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EDITED BY SYDNEY B. J. SKERTCHLY, F.G.S.

AN INTRODUCTION TO

ANIMAL PHYSIOLOGY,

WITH

DIRECTIONS FOR PRACTICAL WORK.

BY

E. TULLEY NEWTON, F.G.S.,

Assistant Naturalist H.M. Geological Survey.

Fifth Edition.

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PREFACE.

THE chief design of this manual is to meet the requirements of pupils preparing for the first-stage examinations of the Science and Art Department in Animal Physiology; consequently due regard has been paid to the syllabus of the Department.

In an elementary work on Physiology much space is necessarily occupied by anatomical descriptions. The course adopted in this manual is to describe each part fully before referring to its uses.

A simple sketch of Human Anatomy and Physiology is given in Chapters I. and II., which will serve as an easy introduction for beginners. Afterwards the various parts are treated of in detail, and this portion, although intended more especially for junior pupils, will, it is believed, be found serviceable to more advanced students.

The importance to the student of having practical acquaintance with the objects studied, has been fully recognised throughout the work. And an endeavour is made to smooth the difficulties which beginners usually experience by giving such instructions as will enable the pupil from the outset to begin working for himself.

The final chapter is devoted to Practical Histology. In the body of the work the minute structure of many organs is described; but as the preparation of the various parts for examination with the microscope requires considerable skill, it has been thought advisable to defer giving instruction in this branch until the student has acquired some proficiency in ordinary dissection.

The practical work required of the pupil is graduated, commencing with the simplest operations, and terminating with such as require more skill and knowledge on the part of the operator.

For much of the matter of the work, the author desires to acknowledge his indebtedness to the writings and lectures of Professor Huxley; and also to the works of Carpenter, Foster, Kirke, Kölliker, Klein, Marshall, Quain, Rutherford, Sanderson, etc.

The source of most of the illustrations is acknowledged in the text; the rest will be found in the works of Bourgery and Jacob, Kiernan, Marshall, Quain, and Sappey. The whole, numbering nearly one hundred, have been drawn for the most part by Mrs. Skertchly, to whom the author desires to tender his best thanks; as also to Mr. Irons for care bestowed in engraving them. E. T. N.

August, 1875.

SECOND EDITION.

THE rapid sale of the First Edition affords an early opportunity of correcting a few trifling errors, and of making sundry improvements in the text. The author also takes occasion to strongly recommend pupils to make drawings of all their dissections, and of the various histological structures exhibited by the tissues under the microscope.

November, 1875. E. T. N.

FIFTH EDITION.

IN this Edition the work is further improved by the addition of a complete series of Examination Questions.

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ANIMAL PHYSIOLOGY.

INTRODUCTION.

Animal Physiology is that branch of *Biology*, or the Science of Life, which treats of the *uses* of the various parts or *organs* of Animal Bodies. *Anatomy* is another branch, which deals specially with the *construction* and *arrangement* of the different *organs*. The study of those more delicate structures of the organs which require the aid of the microscope for their examination, is termed *Histology*.

As it is impossible properly to understand the uses of the different parts, without a knowledge of their structure and arrangement, it becomes necessary to some extent to study *Anatomy* before or together with *Physiology*. And as it is of the greatest importance to have a knowledge of the structure of the Human Body, while at the same time more is known about it than about the bodies of any of the lower animals, it has been deemed advisable to devote the first chapter to a general view of *Human Anatomy*.

In a work like the present, technical terms cannot be avoided, and some are so frequently used that it will be well to explain their meaning at the outset.

Any portion of the body set apart for a special use is termed an *organ*, and the office which it subserves is called its *function;* thus, the function of the organ called the eye is sight.

Living bodies are termed *organisms*, because they all possess organs of greater or less complexity,

Substances which are solely derived from organisms are termed *organic*, such as bone, hair, fat, gelatin, etc.; while substances obtainable from other sources are called *inorganic:* for example, lime, salt, etc.

The manner in which any part is built up is commonly spoken of as *its structure*, and the entire part is frequently called *a structure:* for instance, an organ may be described as a simple or complex *structure;* or we may say that its *structure* or construction is simple or complex.

The elementary *structures* of which any organ is composed are called *tissues:* for example, we speak of *bony* or *osseous tissue*, of *muscular tissue*, and of *nerve tissue;* a delicate membranous substance, which is found very constantly throughout the body, and serves to bind the parts together, is termed *connective tissue*.

Many tissues consist of a great number of minute rounded particles, termed cells (p. 158), and are hence called *cellular tissues;* the *epidermis* or outer layer of the skin, is a good example of this kind of tissue.

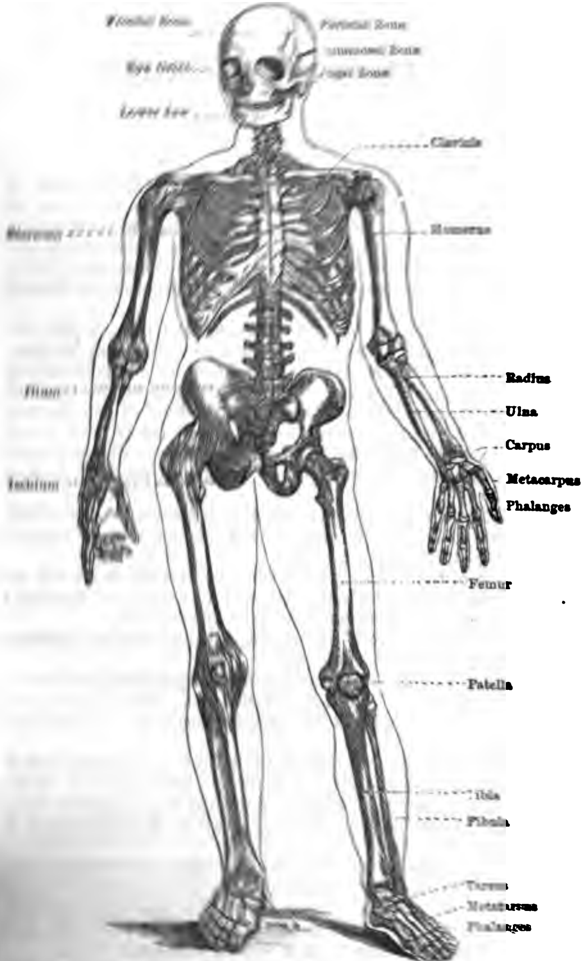

Fig. 1. Human Skeleton. The ligaments have been left upon the right side.

CHAPTER I.

HUMAN ANATOMY.

General Structure of the Body. A glance at the human body shows that it consists of a number of distinct parts, as the *head*, the *trunk*, the upper limbs, or *arms*, and the lower limbs, or *legs*. Each of these parts is as distinctly separable into other portions.

Thus the *head* comprises the *face* and the *cranium*, or brain-case. The face is made up of the parts commonly called *features;* viz., the eyes, nose, mouth, etc.

The *trunk* is divided into an upper portion called the chest, or *thorax*, and a lower named the belly, or *abdomen*.

Each *arm* consists of *upper arm*, *lower arm*, *hand*, and *fingers;* and each *leg* of *thigh*, *leg* proper, *foot*, and *toes*.

The body is completely ensheathed in a tough covering called the *skin*, which is provided with hairs over almost the whole of its surface, those upon the head and face being the most obvious. At the various apertures of the body, such as the mouth, nose, etc., the skin seems to stop and be replaced by a much more delicate structure, which, on account of its continually giving out a viscid fluid called *mucus*, is known as *mucous membrane*. The mucous membrane is a continuation of the skin, and lines all cavities of the body opening externally.

When the skin is removed, the *muscles*, which are the chief (p. 145) organs of motion, come into view. They form the greater part of the *fleshy* portions of the body, and consist of red fleshy masses or bundles of various shapes, which possess the power of contracting, under certain influences. Each muscle is covered by a membranous sheath composed of *connective tissue* (p. 2), which, in many muscles, becomes thicker towards the ends, forming the strong cords, or *tendons*, by which these muscles are attached to the bones or other parts.*

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* For further account of muscles see pp. 147, 149, etc.

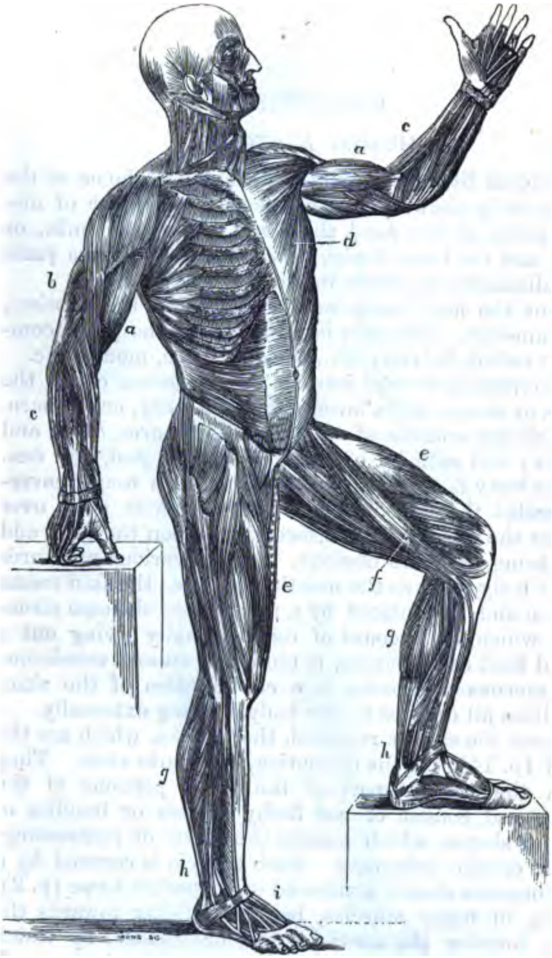

FIG. 2. Body with the skin removed, and partly dissected to show the muscles. The superficial muscles have been removed from the right side of the trunk: *a*, biceps, or flexor muscle of the lower arm; *b*, triceps, or extensor of the lower arm; *c*, muscles which move the hand and fingers; from these white tendons are seen passing to the fingers; *d*, pectoral; *e*, the muscle which straightens the lower leg upon the thigh; *f*, sartorius, or tailor's muscle; *g*, gastrocnemius, connected with the heelbone by means of the Achilles tendon, *h*; it serves to extend the foot upon the leg; *i*, tendons of the muscles which move the toes.

The Skeleton, or Internal Support of the Body. The body is supported by a strong and firm but mobile framework called the *skeleton*, composed of a considerable number of *bones* and *cartilages* (p. 162).

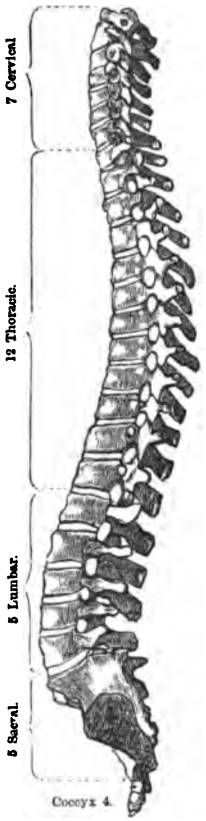

FIG. 3. Side view of the vertebral column.

The skeleton not only gives support to the other portions of the body, but some of its parts act as rigid bars or levers, which are set in motion by the contractions of the muscles. Other parts serve as a protection to the more delicate organs.

A front view of the skeleton is given in fig. 1. It is divisible, like the body generally, into trunk, head, and limbs. Each of these parts will now be considered separately.

Bones of the Trunk. The bones of the trunk are the vertebræ, ribs, sternum, pelvis, scapulæ, etc.

The vertebræ. The chain of bones known as the *vertebral column*, or backbone (fig. 3), forms the principal support of the trunk. It is composed in infancy of 33 segments, or vertebræ; certain of which become firmly united as life advances, so that the number of separate bones in an adult is less than in a young child. The first seven vertebræ, counting from the top, are called *cervical;* then follow the twelve *thoracic* vertebræ, to which the ribs are attached; next come the five *lumbar* vertebræ; following these, come five vertebræ, which, at an early period of life become united, and form one bone, which is termed the *sacrum*. The last four frequently unite, and form what is called the *coccyx*.

With the exception of the first cervical and those forming the coccyx, each vertebra consists of a body, or *centrum* (fig. 4, *a*) surmounted by an arch, termed the *neural arch*, the upper part of which is elongated to form the *neural spine*. On each side of the vertebra there is a projection called a *transverse process*.

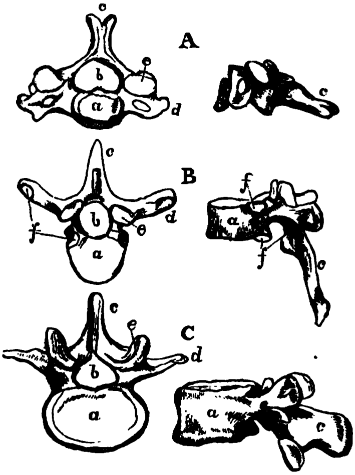

FIG. 4 *A*, a cervical; *B*, a thoracic; *C*, a lumbar vertebra; seen from above in the left figures and from the side in the right figures; *a*, centrum; *b*, neural canal; *c*, neural spine; *d*, transverse process; *e*, surface which articulates with the next vertebra; *f*, surface for articulation with rib. (*Marshall*.)

The bodies of the vertebræ are held together, and at the same time separated from each other, by a fibrous kind of cartilage (p. 162), which is sufficiently elastic to admit of a certain amount of movement in the vertebral column.

The *neural canal* is shown in section, together with the bodies of the vertebræ, in fig. 5.

The Ribs. Each thoracic vertebra has two ribs attached to it, one on each side; and as there are twelve thoracic vertebræ there are consequently twenty-four *ribs*, twelve on each side. The ribs lie in the walls of the thorax, and serve as a protection to the important organs which it contains.

The Sternum. In the front of the thorax is a bone called the *sternum* (fig. 1), to which the upper ten ribs are attached by what are termed the *costal cartilages.* The last two ribs are not connected with the sternum, and are termed *floating ribs.*

The Pelvis. Attached to the *sacrum* upon each side is a bone of irregular form termed the *os innominatum* (fig. 6). It consists of three portions, which in infancy are three separate bones. The upper portion is termed the *ilium*, the lower and hinder the *ischium*, and the lower and front, the *pubis*. These three bones meet in the centre of the *os innominatum*, and form a deep cup, termed the *acetabulum*, into which the head of the thighbone fits. The two pubes meet in the middle line in front. The two *ossa innominata*, with the *sacrum* and the *coccyx*, form the *pelvis*.

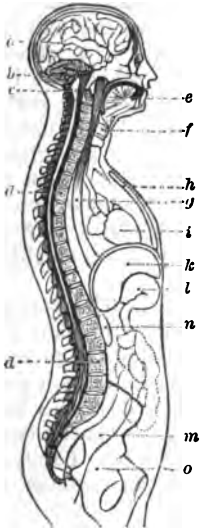

Fig. 5. Longitudinal section of the head and trunk, showing the relation of cavity of the body to that of the cranium and neural canal. Partly diagrammatic: *a*, cerebrum; *b*, cerebellum; *c*, upper part of spinal cord, which continues downwards in the neural canal; *d*, bodies of the vertebræ cut through; *e*, tongue; *f*, larynx; *g*, œsophagus; *h*, sternum; *i*, heart; *k*, liver, directly above which is the diaphragm; *l*, stomach; *m*, rectum; the intestines are simply indicated by a few dotted lines; *n*, the kidney; *o*, pelvic bone.

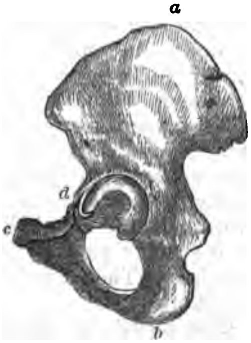

Fig. 6. Left pelvic bone, or os innominatum (one-sixth natural size): *a*, the ilium; *b*, ischium; *c*, pubis; on the right of *d* is the acetabulum or socket into which the head of the femur fits.

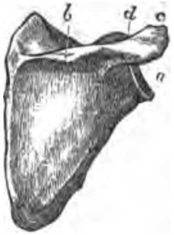

Fig. 7. Right scapula, outer or posterior surface (one-sixth natural size): *a*, glenoid cavity, which articulates with humerus; *b*, spine or crest, ending in the acromion process, *c*; the coracoid process, *d*, is in this view partly hidden by the acromion.

The Scapulæ, etc. Upon each side of the upper and back part of the *thorax* there is a bone termed the *scapula*, or bladebone (fig. 7). Its shape is that of an irregular triangle, the base of which is turned towards the spinal column; the opposite angle, directed upwards and outwards, becomes enlarged so as to form a cup-like depression called the *glenoid cavity*, to which the bone of the upper arm is attached. Upon the outer surface of the scapula there is a *crest* or spine, which extends across its upper part, and projects over the glenoid cavity, where it forms the *acromion process*. From this process a bone called the *clavicle*, or collar-bone, extends to the upper part of the *sternum*, to which it is firmly attached. The *scapulæ* are kept in position chiefly by muscles.

The Skull, or Bones of the Head. The bones of the head are generally separated into two main divisions (1) those of the *cranium*, (2) those of the *face*.

In a very young child the *skull* consists of a great number of separate bones; but as life advances these become more and more united. It is generally stated that in the skull of an adult there are *twenty-two* separate bones, of which eight form the *cranium*, and fourteen the *face*.

1. *Bones of the Cranium.* The *cranium*, that part of the skull which contains the brain, consists of the following bones: (*a*) the *frontal* bone which forms the forehead (fig. 8, 1).

(*b*) Behind the frontal are the two *parietals*, which form part of the upper and side walls of the brain cavity.

(*c*) Then follows the *occipital* bone upon the back of the head, which passes to the under surface, and is here pierced by a large aperture, termed the *foramen magnum*, through which the *spinal cord* passes to the brain.

(*d*) The *sphenoid bone* situated upon the under side of the cranium, joins the *occipital*, and has its winglike sides united to the frontal and parietals.

(*e*) The *ethmoid* bone, which is in front of the *spheroid*, separates the cranial cavity from the chambers of the nose; this bone also sends down a perpendicular plate between the two nasal chambers.

(*f*) Upon each side of the skull is the bone known as the *squamosal* or *temporal bone*, which contains the organ of hearing.

2. *Bones of the Face.* The fourteen bones usually reckoned as belonging to the face are as follows:—

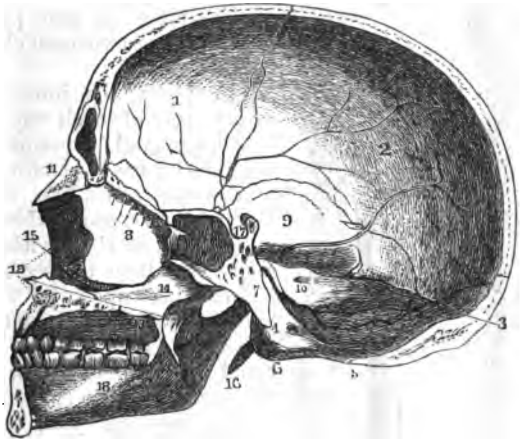

FIG. 8. Longitudinal section of the skull, a little to the left of the middle line. View of the interior: 1, frontal bone; 2, parietal; 3, occipital; 4 and 5, anterior and posterior borders of the foramen magnum; 6, right occipital condyle, which articulates with the first vertebra of the neck; 7, portion of occipital which is continuous in front with the hollow sphenoid; 8, perpendicular plate of ethmoid; 9, squamosal portion of temporal bone; 10, its petrous portion, just above this number is the passage for the auditory nerve; 11, nasal bone; 12, superior maxillary; 13, palatine; 14, vomer; 15, inferior turbinal; 16, styloid process of the temporal, to which the hyoid is attached; 17, sella turcica, which lodges the pituitary body of the brain; 18, lower jaw. (*Quain.*)

(*a*) Two *nasal* bones forming the upper part of the nose.

(*b*) Two *superior maxillaries* bearing the teeth of the upper jaw, and, meeting in the middle line, form the front part of the roof of the mouth.

(*c*) Upon each side is the *malar* or *jugal* bone, extending from the superior maxillary backwards to the temporal bone.

(*d*) Attached to the inner and back portion of the superior maxillaries are the two *palatines*, which also form part of the roof of the mouth, and, with the maxillaries, separate the mouth from the nasal chambers.

(*e*) The *vomer*, a single bone which runs from before backwards, directly above the line in which the two superior maxillaries meet: this bone is immediately below the perpendicular plate of the ethmoid, and partly separates the two nasal chambers.

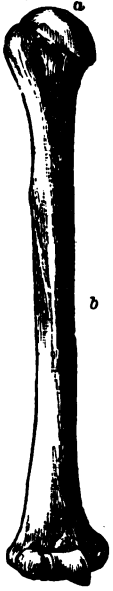

Fig. 9.

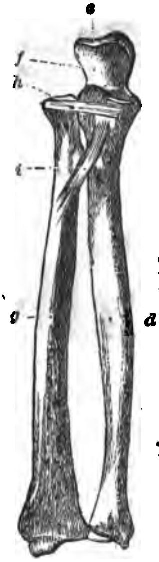

Fig. 10.

FIG. 9. Right humerus, front view (about one-fifth): *a*, head for articulation with scapula; *b*, shaft; *c*, surface for articulation with radius and ulna.

FIG. 10. Right radius and ulna (about one-fifth): *d*, ulna; *e*, olecranon process; *f*, surface for articulation with humerus; *g*, radius; *h*, orbicular ligament attached to ulna and passing round upper part of radius; *i*, check ligament. (*Marshall.*)

(*f*) Upon the inner and upper part of each superior maxillary, and consequently within the nasal chamber, is a delicate scroll-like bone, termed the *inferior turbinal.*

(*g*) Each of the cavities, or *orbits*, in which the eyes are lodged, has upon its inner side a small bone, called the *lachrymal* bone, pierced by a canal which opens below into the nasal chamber (p. 140).

(*h*) The *lower jaw*, or *inferior maxillary* as it is sometimes called, is commonly reckoned as one bone.

The Hyoid. The *hyoid* is not usually reckoned as belonging to the face; it consists of several bones which are placed in the back part of the tongue, and is attached to the skull by two cords, or *ligaments.*

Bones of the Arm. The upper arm has one bone called the *humerus* (fig. 9), the upper end of which possesses a rounded head, to articulate, or join, with the glenoid cavity of the scapula. The lower end articulates with the two bones of the lower arm.

The lower arm possesses two bones, the *radius* and *ulna* (fig. 10). These bones move, not only upon the end of the humerus, but also upon one another. The *ulna* projects behind the humerus, and forms the elbow. When the arm hangs down and the palm of the hand is turned forwards, the *ulna* is upon the inner and the radius upon the outer side, the two being parallel. When the back of the hand is turned forwards, the upper end of the radius turns upon its axis, while the lower end passes over the ulna, so that they become crossed, the thumb being carried over with the radius.

When the radius is parallel to the ulna, the hand is said to be *supine;* but when the radius lies across the ulna, the hand is said to be *prone.*

The *hand* is divided into three parts: (*a*) the *carpus*, or wrist; (*b*) the *metacarpus*, or palm; and (*c*) the *digits*, or fingers. The *carpus* contains eight bones, arranged in two rows. The *metacarpus* is composed of five bones, corresponding to the five digits. The thumb, or first digit, has two bones, while all the other digits of the hand have three each. The bones of the digits are termed *phalanges.*

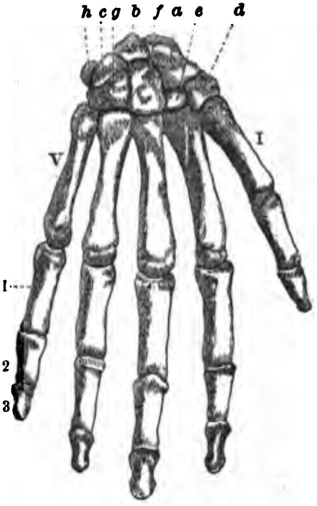

Fig. 11. Bones of the right hand, back view (one-third): *a*, scaphoid; *b*, semilunar; *c*, cuneiform; *d*, trapezium; *e*, trapezoid; *f*, magnum; *g*, unciform; *h*, pisiform; I. to V. metacarpals; 1, 2, 3, phalanges. (*Quain.*)

Bones of the Leg. The thigh has one bone, the *femur* (fig. 12), the upper rounded head of which fits into the acetabulum of the os innominatum. The lower end of the femur possesses two rounded surfaces, termed the *inner* and *outer condyles.*

The *leg* proper has two bones; the *tibia* and the *fibula* (fig. 13), which are not movable upon one another. The upper end of the tibia is broad, and has two depressions corresponding to the two condyles of the femur. The *fibula* is a slender bone, and has no share in the formation of the knee-joint.

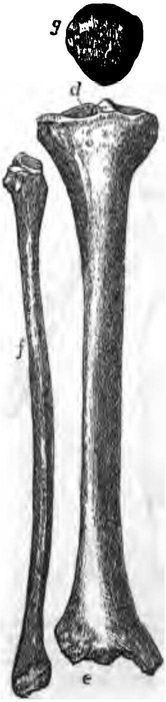

Fig. 13.

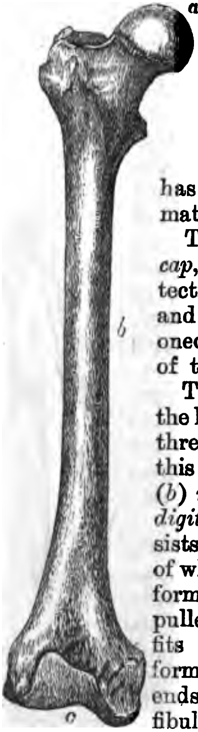

Fig. 12.

Fig. 12. Right femur, front view (about one-fifth): *a*, head, which articulates with acetabulum of pelvis; *b*, shaft; *c*, condyles for articulation with tibia.

Fig 13. Right tibia, fibula, and patella (about one-fifth): *d*, surface of tibia articulating with femur; *e*, surface articulating with foot; *f*, fibula; *g*, patella.

The *patella*, or *knee-cap*, is a small bone protecting the knee-joint, and is generally reckoned as one of the bones of the leg.

The *foot* (fig. 14), like the hand, is divided into three parts, termed in this case (*a*) the *tarsus*, (*b*) *metatarsus*, and (*c*) *digits*. The *tarsus* consists of seven bones, one of which, the *calcaneum*, forms the heel; while a pulley-like bone, which fits into the socket formed by the lower ends of the tibia and fibula is termed the *astragalus*. The *metatarsus* contains five bones; and of the five digits, the first has two *phalanges*, and the rest three each.

Modes of Articulation of Bones. The bones of the skeleton are held together in several ways. In some cases they become firmly united by bony matter, as in the vertebræ forming the *sacrum*. In others, as in the skull, they are united by toothed edges or simply overlap, unions of this kind being termed *sutures*.

Other bones are united by the interposition of cartilage, which is firmly attached to both the bony surfaces. The bodies of the vertebræ are united in this manner, and the ribs are similarly connected with the sternum by the interposition of the *costal cartilages*.

When bones are freely movable upon one another they form what are commonly known as *joints*. In such cases the articulating surfaces of the bones are covered by a thin layer of smooth cartilage, and are kept in position by strong fibrous bands called *ligaments*, which are so arranged as to keep the bones firmly together, while allowing them to move upon one another. The various kinds of joints will be considered in another place (p. 149).

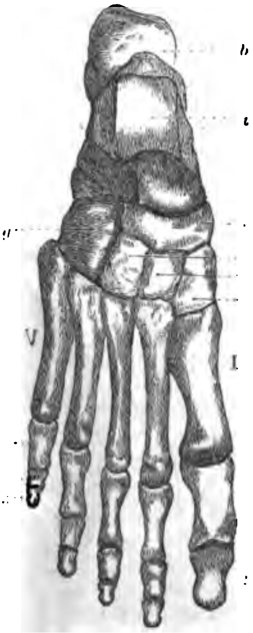

FIG. 14. Right foot, upper surface (one-third): *a*, astragalus; *b*, calcaneum; *c*, navicular (or scaphoid); *d*, internal, *e*, middle, *f*, external cuneiform; *g*, cuboid; I. to V., metatarsals; 1, 2, 3, phalanges. (*Quain.*)

Contents of the Thorax. The general arrangement of the organs in the cavities of the body has now to be considered. When the front wall of the thorax is removed, as shown in the upper part of fig. 15, the greater part of the organs which it contains may be seen.

The Heart. (Fig. 30). This most important organ is placed nearly in the middle of the thoracic cavity. It is a muscular body of conical form, with the base turned partly upwards, and the point directed downwards, and towards the left side. It contains four chambers, with which the arteries and veins communicate. Two of these chambers, situated at the upper part of the heart,

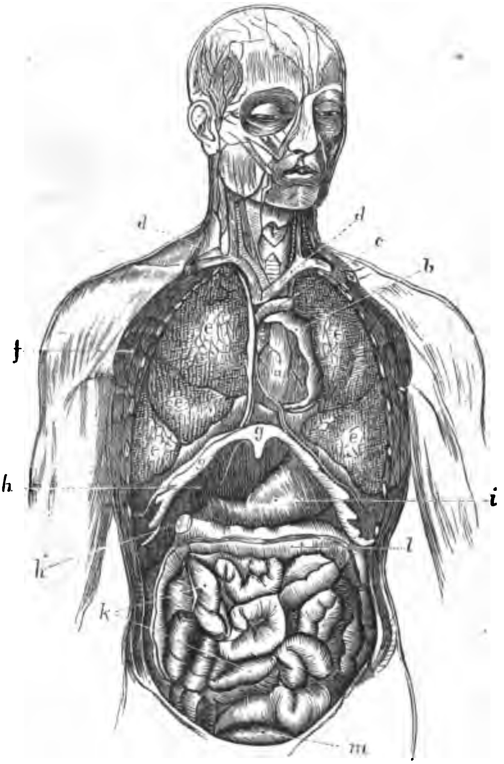

FIG. 15. Thorax and abdomen opened to show the viscera in place: *a*. heart; *b*. pericardium, partly removed; *c*. aorta; *d*. veins; *e*. lungs; *f*, muscles of the walls of the thorax, which have been cut through; the cut ends of the ribs are seen near the lungs; *g*, the tip of the sternum and ends of the lower ribs, to which the diaphragm is attached; *h*, liver; *i*, stomach; *k*, small intestine; *l*, large intestine; *m*, urinary bladder.

have thin walls, and are termed the *right* and *left auricles.* The other two chambers, occupying the lower part of the heart, have thick walls, and are called the *right* and *left ventricles.* The *heart* is enclosed in a membranous bag, called the *pericardium.* The mouth of this bag is attached to the large vessels passing off from the upper part of the heart. The membrane, however, does not end here, but is turned inwards, and reflected over the entire surface of the heart. In this way a bag is formed within a bag, leaving between them a closed space, which contains a fluid termed the *pericardial fluid.* The part of the membrane forming the inner bag adheres closely to the heart.

The heart is the organ by which the blood is forced through the set of tubes or vessels called *arteries* ana *veins*, in order that this most important fluid may be distributed to all parts of the body.

Bloodvessels. The vessels by which the blood is carried *away from* the heart are the *arteries*, while those bringing the blood *back to* the heart are termed *veins.*

From the upper part of the *left ventricle* arises a large artery termed the *aorta*, which arching upwards and backwards comes to lie against the back wall of the thorax, and then descends towards the abdomen. From this *arch of the aorta* three large arteries are given off, one of which very soon divides into two, so that there are virtually four of these vessels. Two of these, the *right* and *left subclavian arteries*, pass to the right and left arms. The other two, the *right* and *left carotid arteries*, run up on either side of the neck to supply the head.

From the upper part of the *right* ventricle, another large vessel, the *pulmonary artery*, passes off, and divides into two branches, one going to each lung. Other vessels pass from the lungs back to the *left auricle*, these are the *pulmonary veins.* The vessels which bring back the blood from the head and upper parts of the body, open into one large vein, the *superior vena cava.* The *inferior vena cava* receives the blood returning from the lower parts of the body. Both *venæ cavæ* open into the *right* auricle.

The Lungs. At the sides of the thoracic cavity are the two *lungs.* When the thorax is entire, the lungs occupy by far the greater part of its cavity, and are in contact with its walls; but when the thorax is opened, the lungs immediately shrink very considerably. Each lung is contained in a double-walled sac termed a *pleura,* which is similar to the pericardium. The inner wall of each *pleura* is attached to the surface of the lung, and the outer wall is in contact with the wall of the thorax. From each lung a large tube, or *bronchus,* arises. These join to form the *trachea,* which passes upwards and opens into the *pharynx* at the back of the mouth. The *trachea* is the passage by which air passes to and from the lungs.

The Œsophagus. Directly behind the trachea, and attached to it, is the *œsophagus,* the upper and enlarged portion of which is termed the *pharynx.* The œsophagus is a wide tube communicating with the mouth above, and passing downwards into the *stomach:* it is the passage by which the food is conveyed from the mouth.

The Diaphragm. The floor of the thoracic cavity is formed by a strong partition, partly muscular, called the *diaphragm,* which separates the thoracic from the abdominal cavity. The œsophagus, bloodvessels, etc., which pass from one of these cavities to the other, have to pass through the *diaphragm.*

Nerves. A double series of white-looking bodies, connected by delicate white cords, forms an irregular double chain upon the back of both the abdominal and thoracic cavities: these are the chief parts of what is termed the *sympathetic nervous system.*

Contents of the Abdomen. *The Stomach.* Soon after passing through the diaphragm the œsophagus opens into the *stomach,* a muscular sac, pyriform in shape, with thick strong walls. The larger, or *cardiac* end of the stomach receives the œsophagus; while the smaller, or *pyloric* extremity is continued into the intestine.

The Intestines. The *duodenum*, as the first portion of the intestine is called, is continuous with the *small intestine*, which forms the greater part of the convoluted mass seen when the abdominal cavity is opened. The

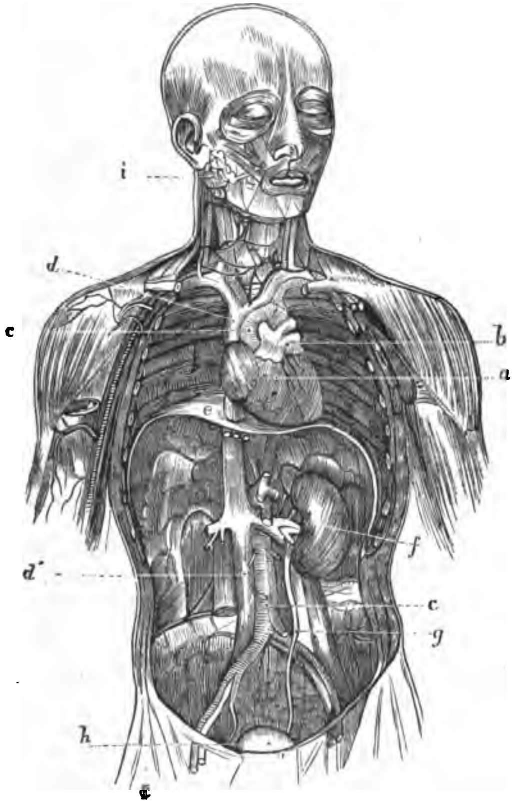

Fig. 16. Thorax and abdomen opened, and most of the organs, including the right kidney, removed: *a*, heart; *b*, pulmonary artery; *c*, aorta; *d*, superior, and *d'*, inferior vena cava; *e*, diaphragm; *f*, the left kidney; *g*, its ureter; *h*, bladder; *i*, parotid gland.

small intestine opens upon the right side of the body into the *large intestine*, which at this point forms a dilatation termed the *cœcum*. After passing across the abdominal cavity, the large intestine turns downwards and backwards, terminating at the anal aperture.

The Liver and Gall Bladder. Immediately below the arch formed by the *diaphragm* is the *liver*, a large red organ, divided into several portions or *lobes*, and partly overlapping the pyloric end of the stomach. On turning up the lobes of the liver, a small greenish-coloured bag is seen. This is termed the *gall-bladder*, and is the receptacle for the *gall* or *bile*, a fluid formed by the liver for use in the process of digestion. The bile is poured into the duodenum through a small tube called the *biliary* or *hepatic duct.*

The Pancreas and Spleen. These are two organs which are also situated near to the *stomach;* the latter being close to its cardiac portion.

The Kidneys and Bladder. When the stomach and intestine are removed, the two *kidneys* may be seen. From each of these organs a tube called the *ureter* passes downwards, terminating in the lower part of the bladder, which is placed at the bottom of the abdominal cavity towards the front (fig. 16).

Bloodvessels. The *aorta*, after passing through the diaphragm, gives off branches to the liver, stomach, intestine, kidneys, etc., and afterwards divides into two main channels, the *right* and *left iliac* arteries, which pass to the lower limbs.

The *inferior vena cava* runs up beside the aorta, and passes through the diaphragm on its way to the heart.

The Peritoneum and Mesentery. The interior of the abdomen is lined by a membrane termed the *peritoneum;* this is reflected over most of the organs contained in the cavity in a manner similar to that in which the pleuræ cover the lungs. The portion of the peritoneum reflected over the intestine is attached to the back wall of the abdominal cavity, and forms a membranous expansion termed the *mesentery*. The intestine, enclosed in its fold of peritoneum, is supported by being thus attached to the edge as it were of the mesentery.

The Cavities of the Skull and Spinal Column. When a human body is cut down the middle line into two lateral halves, as shown in fig. 5, the bodies of the vertebræ, which have been cut through, will be seen separating the thoracic and abdominal cavities which are situated upon their front or *ventral* aspect, from the much smaller cavity of the *neural canal* seen at their back or *dorsal* surface. The spinal canal, formed by the neural arches of the vertebræ, becomes gradually smaller at its lower part; but is continuous above with the *cavity of the skull* (fig. 17).

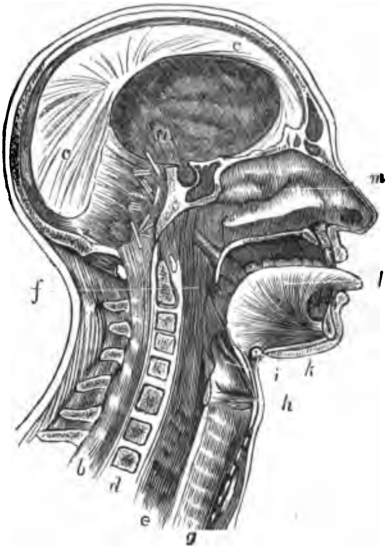

FIG. 17. Vertical section through the head and neck *a*, cavity of skull, the brain having been removed; just below this letter the cut ends of some of the cranial nerves are seen; *b*, neural canal; *c*, membranous partition, called the falx, which is found between the two hemispheres of the brain; *d*, bodies of vertebræ cut through; *e*, œsophagus, communicating above with *f*, the pharynx; *g*, trachea; *h*, larynx; *i*, epiglottis; *k*, hyoid; *l*, tongue; *m*, nasal cavity.

In the trunk the ventral or abdominal and thoracic cavities are much larger than the dorsal cavity, or spinal canal. In the head this is reversed, the ventral cavity, formed by the mouth and nasal chambers, being smaller than the dorsal cavity, or brain case.

The Brain and Spinal Cord. The great cavity of the human skull is chiefly occupied by two large convoluted masses of the brain called the *cerebral-hemispheres* (figs. 5, *a*, and 50); below the hinder part of these hemispheres is situated that portion of the brain called the *cerebellum* (figs. 5, 53). The base of the *brain* is continued into the *spinal cord*, a greyish white substance extending along the spinal canal as far as the second lumbar vertebra, where it becomes reduced to a mere thread. This *filum terminale*, as it is called, with certain nerves given off from the lower parts of the spinal cord, occupies the remaining portion of the neural canal.

Nervous cords pass from the brain to the eyes, nose, mouth, ears, and other parts of the head and body. From the spinal cord similar threads pass out on each side of the canal, between the arches of the vertebræ, and, dividing and subdividing, are distributed to all parts of the body.

Membranes surrounding the Brain and Spinal Cord. The *brain* is covered by a very vascular membrane termed the *pia mater*, which dips down between all the irregularities of its convolutions. The interior of the skull is covered by a very strong, tough membrane called the *dura mater*, which adheres firmly to the surrounding bone. The free surface of both these membranes is covered by a very delicate layer of membranous tissue, the *arachnoid*, which, being reflected from one to the other, forms a shut sac, similar to the *pericardium* (p. 15).

The *spinal cord* is protected by the same membranes as the brain (fig. 46); but the *dura mater* is not attached to the surrounding bones.

PRACTICAL SECTION.

The student is recommended to follow out for himself the directions for practical work which are given throughout this manual, and not to be content with simply reading the descriptions, or even with seeing dissections and experiments performed by others; but to work the matters out with his own hands. [See Appendix.]

Dissection of an Animal.—All the parts of the body described in the foregoing chapter may be conveniently studied by dissecting some small animal, such as a *cat*, a *dog*, or a *rabbit*.

A rabbit is most easily obtained, and for certain other reasons is perhaps best suited for this purpose. It should be obtained alive, and then killed by drowning or by chloroform. The ordinary method of killing rabbits practised by dealers, spoils the animal for dissection. Young pupils are advised to consult some experienced person as to the best mode of killing the animal so as not to give it pain unnecessarily. The dead animal should be laid upon its back upon a table or board, into which stout pins may be driven, and a piece of string tied to each limb and attached to four pins driven into the board for that purpose. The skin of the thorax should then be cut through in the middle line with a sharp knife, and the cut extended forwards to the *chin*, and backwards to the lower part of the abdomen, so that the skin may be turned back. The latter operation should be done as far as possible without using the knife.

Muscles. The muscles of the abdomen and thorax thus exposed, are seen to be covered with a thin membrane. The limbs of one side may now be untied, and the skin removed from them, and then stripped off the body as far as the middle line of the back. The muscles of the limbs and back are now seen.

The membrane covering the muscles, say of the hind leg, should be dissected off. To do this the membrane should be raised carefully with a pair of forceps, and the portions by which it is attached cut through with the knife, care being taken not to cut the muscles.

One of the muscular bundles should now be traced from end to end. For this purpose raise the centre, or *belly*, of the muscle, and with the point of the knife cut through the membranes which adhere to it, always taking care not to cut the muscle itself. Continue to separate in this manner the muscle from the surrounding parts until the point is reached where it is attached to the bone; then in the same way expose the opposite end of the muscle.

Abdominal Cavity. The animal being turned upon its back, the front wall of the abdomen is to be cut through, from just below the sternum to its lower part, care being taken not to injure the organs within. From the upper part of this incision another is to be made at right angles to it, and just below the ribs; this transverse incision is to be carried back as far as possible on both sides. A similar transverse cut is then carried across the lower part of the abdomen, and the flaps thus made turned back.

The organs which are in this manner displayed should be compared with the figures and descriptions given in the foregoing chapter.

Turn the animal on its side, and cut away the flap of the abdominal wall of the upper side as close to the vertebræ as possible. The relation of the organs will then be still better seen, and other parts, before hidden, will come into view. The intestine should be raised carefully out of its place, and the mesentery, by which it is supported, examined; the bloodvessels and nerves which ramify through the mesentery should also be noticed.

The mesentery may now be cut through near its attachment to the spinal column, so that the intestine may be removed, and the stomach, liver, kidneys, etc., examined.

Thoracic Cavity. The thorax is to be opened by cutting across from one side to the other a little above the lowest ribs so as to leave a band between the opening in the abdomen and that now being made in the thorax. This band is left so that the attachment of the diaphragm to this portion may be studied when the larger organs have been removed. The sternum and ribs, which have now to be divided, may be cut through with scissors. The cut end of the sternum is held with the forceps, and somewhat raised, while the ribs are divided as near each side as possible. The vessels passing to the limbs, near the upper part of the thorax, must *not* be cut through. The portion of the front wall of the thorax thus raised is to be cut across at its upper part, and removed.

The lungs and heart which are thus exposed, together with the large vessels and other parts, should be compared with the figures and descriptions given in the text. The large vessels going to the limbs, lungs, etc., should be traced.

The Brain and Spinal Cord. These parts are somewhat more troublesome to expose than those which have just been described, but with a little care it may be accomplished. For this purpose the back of the animal should be turned upwards, and the limbs secured as at first. The skin is removed from the head, by making a longitudinal incision in it, and then turning it back upon each side. The muscles upon the sides and back of the skull should next be cleared away. A hole may now be made in the top of the skull with the point of a pair of scissors, and the bone broken away piece by piece with a pointed pair of nippers until the upper surface and sides of the brain can be seen. In a rabbit the cerebral hemispheres do not, as in man, cover the cerebellum, and consequently the latter is seen when the brain is viewed from above.

When the bone has been broken away so as fairly to expose the sides of the brain, the latter should be carefully raised by inserting the tips of the fingers under it on one side, and gently pulling. Several white cords will thus be seen passing from the under surface of the brain to the floor of the skull: these are the *cranial nerves.*

In order to expose the *spinal cord*, the skin of the back must be removed, and the muscles cut away from each side of the spinal column, as close to the bone as possible; then, commencing at the back of the skull, the spinal canal is to be laid open by cutting with the nippers the two sides of each neural arch. Care must be taken not to cut or tear the spinal cord or the nerves passing off from it. When the spinal cord has thus been exposed, and the membranes which surround it made out, the spinal nerves should be examined, and the two roots by which each arises from the cord distinguished, and likewise the swelling or *ganglion* of the posterior root.

The brain and spinal cord should now be removed, by carefully raising them, and cutting through the nerves by which they are attached. Separate the brain from the spinal cord, and place the former in spirits of wine, and the latter, cut in short pieces, in the chromic acid solution (p. 175, No. 4), for future use.

CHAPTER II.

FUNCTIONS OF THE BODY.

Continual Waste of the Body. We have seen that the body is made up of a great number of organs, the uses of which it is the province of physiology to study. Before entering, however, upon a detailed consideration of each part, it will be well to look at the body as a whole, in order to see what are the general results of the performance of its functions.

It is a well established fact that no organ can be in a state of activity without the expenditure of a certain amount of *force*, for the production of which some of the materials existing in the body undergo the chemical change known as combustion. Just as the mechanical power of a steam engine is due to the heat-force generated by the burning of the fuel in its furnace, so by the force evolved in a similar process of burning are the various actions of the body accomplished.

In every part of the body during life the oxygen of the blood is continually entering into combination with certain materials containing carbon and hydrogen, causing combustion, in the process of which heat and force are evolved.

Now as the materials burnt are unfitted for further service in the body, it follows that every action must be accompanied by a waste of material.

In the body of a living man certain functions are being *continually* performed, as for instance the *beating of the heart* and the *process of respiration*, both of which are caused by the action of certain muscles; consequently there must be a *continual wasting of the body.* Other actions are intermittent, such as *standing*, *walking*, *speaking*, etc. These also are accompanied by considerable waste. Not only do these more or less obvious actions necessitate a consumption of material, but all imperceptible actions also, whether of *muscles*, *glands*, or *nerves;* indeed every *thought* is accompanied by a proportionate waste of material.

The average temperature of the human body is about 100° Fahrenheit, and as this is considerably above the ordinary temperature of the surrounding air, a continual radiation of heat takes place from the body. This tends to lower its temperature, and would soon reduce it to that of the surrounding air, were it not compensated for by internal combustion. Here, then, is another cause of continual waste.

Products of Waste. The materials used by the various organs in the exercise of their functions having been rendered unfit for further service in the body, it is necessary that they should be got rid of.

The products of this change or waste consist chiefly of *carbonic acid*, *urea*, *water*, and some saline substances. These are taken up by the blood in its circulation through the body, and conveyed to certain organs whose office it is to separate them preparatory to their being thrown out of the system.

The Organs by which the Products of Waste are separated from the Body. The organs by which this function is performed are the *lungs*, the *kidneys*, and the *skin* (p. 92). The *lungs* get rid of the greatest proportion of *carbonic acid*, with a small proportion of *water* in the form of vapour. The latter may be seen when we breathe in a cold atmosphere: for the vapour, as it passes out of the lungs, becomes condensed, and is then visible. Also when a piece of cold glass (a window pane for example) is breathed on, it becomes covered with moisture from the same cause.

The presence of carbonic acid in expired air may be shown by causing air from the lungs to pass through a clear watery solution of lime. The solution will soon become turbid, owing to the formation of carbonate of lime (p. 87).

The *kidneys* eliminate a very considerable quantity of *urea* and *water;* while the *skin* throws off, in the form of *perspiration*, *carbonic acid* and *water*, and sometimes a small proportion of *urea.*

Compensation for Waste. It is obvious that if the waste indicated above were not made good, the body would soon become considerably reduced in weight. The loss is compensated when the food and water taken into the system are of such a kind and in such quantity as to supply an amount of nutriment to the tissues, equal to the waste which takes place.

If but little or no food be taken, the body gradually diminishes in weight. This happens even when the body is at rest; but during active exercise it takes place much more rapidly. If the wasting be allowed to continue, a point will at length be reached at which death from *starvation* must ensue.

Proofs of Waste. If the body of a healthy man be accurately weighed at intervals during the day, it will be found that its weight is greatest directly after a meal, and gradually decreases until food is again taken. The diminution in weight will be more considerable the longer the period of fasting is extended, or the more the amount of activity is increased.

The continued excretion of carbonic acid, urea, etc., even when the body is not supplied with food, and the loss of weight in consequence of this excretion, are further proofs that waste takes place.

Digestion. The process by which food is prepared for the nourishment of the tissues is termed *digestion*, and takes place in the *mouth*, *stomach*, and *intestines*. That part of the food which has been properly digested is absorbed by vessels in the walls of the stomach and intestine, and poured sooner or later into the *blood-vessels;* these carry it to all parts of the system, for the nourishment of the tissues of the various organs. Those portions of the food which cannot be so absorbed pass out of the alimentary canal as fæces.

Circulation. The blood is the medium by which nourishment is conveyed to the various tissues and by which the waste matters are carried away from them. In order that these two objects may be attained, the blood is kept constantly circulating. The heart is the organ which, by its regular and rhythmical contractions, keeps the blood in motion. The arteries by which this red fluid is conveyed from the heart become gradually smaller and smaller, and their walls get thinner and thinner, until at length they form a delicate network of capillary vessels in the various tissues throughout the body. Here the walls of these vessels are so thin that the nutritious matters contained in the blood pass through them to the minute portions of the tissues which lie in the meshes of the capillaries. Here also waste matters find their way into the blood. It is in these capillaries too that the oxygen, which is perhaps the most essential constituent of the blood, appears to be chiefly made use of, a fresh supply being obtained during the passage of the blood through the *lungs*.

The Nervous System. The nervous system is the governing power of the body. It enables the different organs to perform their functions, and brings the various parts into such relation that they may when necessary act in concert. The motions of the body, it is true, depend upon the movements of the muscles, but the contractions of the muscles, whether voluntary or involuntary, are caused by the influence of the nervous system. The nervous system is also the means by which the body is brought into relation with the outer world. The terminations of certain nerves are modified to enable them to receive impressions; as, for example, in the eye, ear, etc. The sensations of *touch*, *taste*, *smell*, *hearing*, and *sight*, could not however be experienced but for the brain, which alone has the power of *perceiving* sensations.

Death. While the organs are capable of performing their functions, the body is said to be alive; but when they can do so no longer the body is dead. Death may be *local* or *general.*

Local Death. In almost all parts of the body portions of tissue are constantly dying and being carried out of the system as waste; but this kind of *local death* is necessary for the life and health of the body.

When from disease or injury any part of the body ceases to be nourished, *mortification* takes place, or in other words the part *dies.*

General Death. When the heart, the respiratory organs, and the brain, cease to act, the body is ordinarily said to be dead. The tissues may, however, possess their *vital properties* for some time after this has taken place. This is shown by the contraction of muscles when irritated, and by the power which the nerves retain of conveying influences even after separation from the body. It therefore becomes necessary to discriminate between what is *ordinarily called death* and the *death of the tissues.*

Causes of Death. Whatever may be its apparent cause, death is always the direct result of one of three causes, viz.: (1) the cessation of the action of the *heart*, (2) of the *lungs*, or (3) of the *brain and spinal cord.*

Classification of the Functions. The functions of the human body are generally divided into two groups,

(1) *The Vegetative Functions.*

(2) *Functions of Relation, or Animal Functions.*

The first group includes all processes which serve for the growth and nourishment of the body. The second embraces those functions which bring the individual into relation with the outer world.

The following table shows in a general way the functions included in each of these groups, and the organs by which they are performed.

	FUNCTIONS.	ORGANS.
Vegetative Functions.	Digestion:	
	Mastication.	*Teeth.*
	Insalivation.	*Salivary Glands.*
	Deglutition.	*Œsophagus.*
	Chymification.	*Stomach.*
	Chylification.	*Duodenum.*
	Absorption.	*Lacteals, Lymphatics, Blood Capillaries.*
	Circulation.	*Heart, Arteries, Capillaries, Veins.*
	Nutrition.	*Capillaries.*
	Secretion.	*Various Glands.*
	Excretion.	*Kidneys, Lungs, Skin.*
	Respiration.	*Lungs.*
Functions of Relation, or Animal Functions.	Thought.	*Brain.*
	Sensation.	*Brain, Nerves, Sensory organs.*
	Motion.	*Muscles.*
	Voice.	*Larynx.*

CHAPTER III.

CHEMICAL COMPOSITION OF THE BODY.

Proximate Principles. By submitting the various tissues of the body to certain simple processes, such as washing, boiling, etc., a number of different substances may be obtained, which are known as *proximate principles.* The chemical elements which enter into the composition of the proximate principles are *carbon, hydrogen, oxygen,* and *nitrogen,* sometimes united with *sulphur* and *phosphorus.* These are combined in various proportions, and form very complex compounds.

The *proximate principles* are of two kinds: those which contain a proportion of *nitrogen*, and are therefore termed *nitrogenized substances;* and those which do not contain *nitrogen*, and are hence termed *non-nitrogenized substances.* It will be necessary to consider the nature of the most important of these compounds.

Nitrogenized Substances, or Proteids. All these substances contain *carbon*, *hydrogen*, *oxygen*, and *nitrogen*, with a small proportion of mineral matters.

1. *Albumen.* The best known form of this substance is the white of eggs. It is found in the human body in a state of solution, both in the blood and in the fluids of most of the tissues. It possesses the peculiar property of coagulating when heated to about 158° F., and is precipitated by the addition of alcohol, or strong acids, and by most metallic salts.

2. *Globulin.* This is a peculiar kind of albumen, which forms the chief part of the red blood corpuscles (p. 55). It is also found in the crystalline lens of the eye, and is then known as *crystallin.*

3. *Hæmoglobin*, or *cruor.* This is the material contained in red blood corpuscles (p. 59). It may be separated into two parts, *globulin* and the colouring matter which is termed *hæmatin.*

4. *Fibrin.* If some freshly drawn blood be whipped with a bundle of fine twigs, a soft fibrous mass will adhere to them; this substance is called *fibrin*, and differs from albumen in possessing the property of coagulating spontaneously.

Fibrin does not exist as such in the blood, but is the result of the combination of two substances which form part of the plasma of the blood (p. 55). One of these substances, *fibrinoplastin*, is closely allied to, if not identical with, *globulin*. The second substance, *fibrinogen*, exists, not only in blood plasma, but also in *lymph* and *chyle* (pp. 75 and 52).

5. *Syntonin.* This substance is a kind of *fibrin* obtained by treating muscular tissue with dilute acid. Syntonin, as it exists in the muscles, is termed *myosin;* the coagulation of this causes the stiffening of the body,

r *rigor mortis*, which takes place soon after death (p. 146).

6. *Casein.* The chief source whence *casein* is obtained s milk; but it is found, though in much smaller quantities, in other fluids of the body. It remains in solution o long as the milk is slightly alkaline (as it is when uite fresh); but when the milk turns sour, or an acid is dded to it, the casein is coagulated, and forms the white lakes known as *curd*, from which cheese is made. Casein very closely resembles albumen, but differs from it in not being coagulated by heat.

7. *Keratin* or *horny matter.* This is much like albumen, but contains a larger proportion of sulphur. It is the substance of which hair and nails are composed.

8. *Pepsin.* This albuminous substance, is obtained from the *gastric juice.* It gives to that fluid its powerful solvent properties which are so important in the process of digestion (p. 43).

9. *Ptyalin.* An important constituent of the saliva, having the power to convert starch into dextrine, and dextrine into sugar (p. 40).

10. *Gelatin.* When *connective tissue*, *tendons*, *ligaments*, *bones*, etc., are boiled in water, they yield a substance called *gelatin.* A solution of gelatin in water, remains fluid whilst hot, but becomes jelly-like when cold. From weak solutions gelatin may be precipitated by the addition of alcohol, ether, tannic acid, etc.

11. *Chondrin.* This substance is obtained by boiling cartilage in water: the solution solidifies when cold. It closely resembles gelatin, but differs from it chiefly in not forming so firm a jelly when cold.

Non-Nitrogenized Substances. The non-nitrogenous substances contain *carbon*, *hydrogen*, and *oxygen;* but *no nitrogen.* They are of two kinds: the *fats* and he *amyloids.*

1. *The Fats.* These are more abundant than the amyoids, and differ from them in containing a larger mount of carbon and hydrogen in proportion to

oxygen. There are several varieties, one of the differences between them being that they solidify at different temperatures. The more important are *margarin*, *olein*, *stearin*, and *cholesterin*. *Cholesterin* partakes more of the nature of a resin than of a fat. It possesses the peculiar property of remaining solid at the ordinary temperature of the body. It is found in the brain and in bile.

2. *The Amyloids*. *Starch*, *dextrine*, *sugar*, and *gum* are the substances included under this denomination. They all contain less *carbon* and *hydrogen* in proportion to *oxygen* than the fats; the oxygen and hydrogen being in the proper proportions to form water, while in the fats there is an excess of hydrogen.

Glucose or *grape-sugar* is found in the blood which leaves the liver by the hepatic vein. A variety of sugar called *lactin* exists in milk. *Lactic acid*, which is formed from sugar, is found in the blood and in the gastric juice. It is this acid which is formed when milk turns sour.

The Results of Decomposition. The proximate principles are very unstable compounds, having a constant tendency to decompose when left to themselves, or in other words to become resolved into substances of a much more simple chemical composition. A dead body has the same tendency; its various tissues becoming more or less rapidly decomposed, and reduced to the same simple compounds as result from the decomposition of proximate principles, viz., *carbonic acid* ($C\,O_2$), *ammonia* ($H_3\,N$), *water* ($H_2\,O$), and certain mineral substances.

Mineral Substances found in the Body. The following are the more important of the mineral substances which enter into the composition of the body.

1. *Phosphate of lime*, or *bone earth*, exists in small quantities in all the tissues, but is found abundantly in the bones and teeth.

2. *Carbonate of lime* always exists in the bones and teeth, but to a less extent than *bone earth*.

3. Fluoride of calcium is also found in the bones and teeth, and to a less extent in other tissues.

4. Chloride of sodium (common salt) is very generally distributed throughout the body.

5. Iron occurs chiefly in the colouring matter of the blood, but exists also in hair and some other tissues.

The following substances are found only in small quantities:—

6. Phosphates and carbonates of magnesia.

7. Phosphates and carbonates of soda and potash.

8. Sulphocyanide of potassium is generally to be found in the saliva.

Ultimate Chemical Elements. Analysis has shown that the human body is composed ultimately of a number of elementary chemical substances, the greater part of the oxygen and hydrogen present being in the form of water.

The following table gives a general idea of the proportion of the different chemical elements which enter into the composition of the body of a man weighing [illegible] pounds, [illegible] pounds being water and [illegible] pounds solid substance.

	lbs.
Oxygen	[illegible]
Carbon	[illegible]
Hydrogen	[illegible]
Nitrogen	[illegible]
Calcium	[illegible]
Phosphorus	[illegible]
Sulphur	[illegible]
Sodium	[illegible]
Chlorine	[illegible]
Iron	[illegible]
Fluorine	[illegible]
Potassium	[illegible]
Magnesium	[illegible]
Silicon	[illegible]

CHAPTER IV.

FOOD.

Food required by Animals. One of the most important differences between animals and plants is that while plants build up their tissues from such simple *inorganic* compounds as carbonic acid, ammonia, water, and saline matters, animals can only obtain nourishment by making use of *organic* compounds which have been elaborated by plants. In other words, a plant absorbs the simple inorganic compounds,—carbonic acid, ammonia, etc.,—and from them constructs the complex proteid and carbonaceous compounds of which its tissues are composed; while an animal eats either plants or animals which have fed upon plants, and thus derives its sustenance from the proteids, etc., which they contain. In the exercise of their functions the tissues of animals become oxidized and broken down into much simpler compounds, and these ultimately form *carbonic acid*, *ammonia*, *water*, and *saline matters*, from which, as we have seen, a plant is capable of building up its tissues.

In order to nourish the body, food must therefore consist of organic substances, such as exist in bread, butter, meat, vegetables, etc. A man of average size requires daily about 8000 grains of chemically dry solids, besides water; and the lungs will, during the same time, absorb about 10,000 grains of oxygen.

Classification of Food. Food stuffs may be divided into the following classes:—

1. Those used mainly for the *nourishment* of the tissues, and known as *proteids* or *nitrogenous substances* (also termed *plastic*, *nutritive*, *histogenetic*, *albuminous*, or *flesh-forming* materials).
2. Those chiefly concerned in the production of *heat* in the body, termed *heat-producers* or *non-nitrogenous substances* (also called *respiratory*, *carbonaceous*, and *fuel-foods*)
3. The *inorganic materials* required for the maintenance of the body.

These divisions, although convenient, are not strictly correct, inasmuch as the foods of the first class take some part in the production of heat, while those of the second class do something more than simply maintain the temperature of the body.

Proteids. All the nitrogenized *proximate principles*, viz., albumen, fibrin, casein, gluten, etc., derived from animal and vegetable tissues, serve as food stuffs, and belong to this division. It is doubtful, however, whether gelatin or chondrin possesses any nutritive qualities.

Proteid matters are found more or less in all vegetables; the following are the most important:—*Albumen*, existing in the seeds and fluids of most vegetables; *gluten*, found in abundance in *wheat* and other *cereals*, and said to be identical in composition with *fibrin;* and *legumen*, the nitrogenous material obtained from *peas* and *beans*, which in chemical composition is like *casein.*

Heat Producers. Under this head are included the fats or oleaginous matters, and the amyloids—starch, dextrine, sugar, gum. The fats are better heat-producers than the amyloids, because they contain more hydrogen (p. 30). The amyloids are almost wholly derived from vegetables; glucose, however, is also found in animals, it being formed in the liver (p. 50).

Inorganic Food Stuffs. As the composition of the body embraces certain mineral elements, it is necessary for its proper nourishment that small quantities of these *inorganic matters* should be taken into the system. They are generally present in sufficient quantities in our ordinary food stuffs.

Water. Although water is not generally considered food, yet it is indispensable to the well-being of the body, and therefore a certain amount, in some form or other, must be taken daily.

Oxygen is not received into the alimentary canal, and consequently can hardly be termed food, nevertheless it is so essential to the due performance of the functions of the system, that a sufficient quantity must be regularly supplied.

Table of Food Stuffs.

ORGANIC	Proteids (*nitrogenous*)		Gluten Albumen Fibrin Syntonin Casein Gelatin Chondrin	*Oxygen* *Hydrogen* *Carbon* *Nitrogen*
	Heat-givers (*non-nitrogenous*)	*Oleaginous*	Fats	*Oxygen* *Hydrogen* *Carbon*
		Amyloids	Starch Dextrin Gum Sugar	
INORGANIC			Water Saline matters	

Necessity of a Mixed Diet. No one of the classes of food which have been mentioned is capable by itself of keeping the body in health for any length of time. As a matter of fact, however, most of the ordinary foods contain several of the requisite materials; for instance, bread contains both proteids and heat-givers, besides water and saline matters. At the same time these ingredients do not exist in bread in the proportions required by the system.

Milk contains every variety of food necessary for the nutrition of the body and the production of heat, and in such proportions that infants fed upon milk alone grow and thrive.

It has been proved by experiment that animals may live for a very considerable time upon *proteids* alone; but this kind of diet is neither economical, nor likely to keep the body in a healthy condition. Animals, however, which are fed exclusively upon *heat produsers* (sugar, etc.), invariably die very soon. The waste of nitrogenous materials not being made good, the body becomes emaciated. The animal is in fact starved, just as though it had been kept entirely without food.

Economy of a Mixed Diet. It has been estimated that a healthy man of ordinary size throws out of his system daily, as waste matter, about 4600 grains of carbon and 300 grains of nitrogen. Now in order to keep such a man in health it is necessary that his daily food should contain in a convertible form, at least the same amount of carbon and nitrogen. According to Payen 1000 grains of *bread* contain about 300 grains of *carbon* and 10 grains of *nitrogen.* If therefore a man were fed upon *bread* alone, he would require 30,000 grains in order to get the 300 grains of nitrogen; but this amount of bread would yield about 9000 grains of carbon, or nearly double the quantity required.

Again, 1000 grains of *meat* contain about 100 grains of carbon and 30 grains of nitrogen. In order therefore to obtain 4600 grains of carbon it would be necessary to eat 46,000 grains of meat. But this would give 1380 grains of nitrogen, or more than four times the quantity required.

The following table, given by Dr. Carpenter, shows the proportion of bread and meat which should be taken by an ordinary man to supply the system with sufficient carbon and nitrogen to make good the daily loss of these materials without unnecessary waste of either.

Grains.		Grains.		Grains.	
15,440	of Bread contain	4630	of Carbon and	154	of Nitrogen.
4,630	Meat ,,	463	,,	154	,,
20,070		5093		308	

From this table it will be seen that 15,440 grains, or about 2 lbs., of bread, and 4630 grains, or about ¾ lb., of meat, will supply the carbon and nitrogen required daily by an ordinary man. A judicious proportioning of the different kinds of food is thus shown to be economical, for the total amount required is far less when properly mixed than when any one kind of food is taken exclusively.

Variations of Food Requisite. Our daily supply of food requires to be varied, both in kind and amount, according to circumstances. When a person is taking exercise there is a greater waste of tissue than when he is inactive (p. 24); and as this waste of tissue is made good by the materials contained in *nitrogenous* food, it follows that a man will require more nitrogenous food when he is taking active exercise than when he is idle.

The *temperature* of the body is chiefly maintained by the combustion of the amyloids and fats which are taken with the food. Now in cold climates the body loses a greater amount of heat by radiation than it does in warmer climates, consequently a larger proportion of these combustible materials must be taken as food in order to maintain the body at the proper temperature.

An infant requires much more nitrogenous food in proportion to the weight of its body than an adult. This is just what we should expect, when we consider that in a child, not only has the daily waste of the body to be made good, but new tissues have also to be formed or the body would not grow.

CHAPTER V.

ALIMENTARY CANAL AND DIGESTION.

Digestion. In order that food may be absorbed and fitted for the nourishment of the tissues, it must be *digested.* The various *digestive organs* and their special functions will now be considered in detail.

Mouth. The mouth is the cavity into which the food is first conveyed, and in which the first processes of digestion are accomplished; the floor of this cavity is formed by the tongue, and it is bounded above by the palate. The front part of the palate is strengthened by bone, and is called the *hard palate;* the hinder portion has no bone, and is termed the *soft palate.* This soft part is produced behind into the fleshy body known as the *uvula,* which may be seen hanging down at the back of the mouth. The mouth is bounded in front by the *lips* and *teeth*, and at the sides by the *cheeks* and *teeth*.

Teeth. There are two semicircular rows of teeth, one in the upper and one in the lower jaw; each row consisting, in the adult, of 16 teeth; (8 upon each side) making in all 32. Each tooth consists of a *crown* and a *root* or *fang*. The crown is the portion above the gum, covered by a very hard substance called enamel. The fang is embedded in the jaw, and has no enamel.* At the junction of the root with the crown there is a constriction, termed the *neck*. The sockets in the jaws, which receive the fangs of the teeth, are termed *alveoli*.

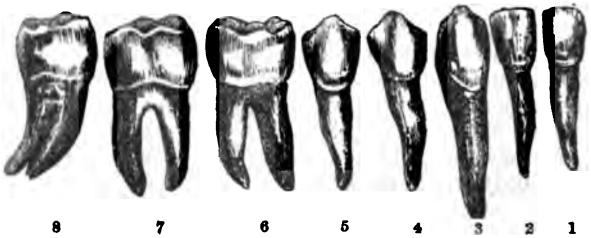

FIG. 18. Teeth: 1, 2, incisors; 3, canine; 4, 5, bicuspids or premolars; 6, 7, 8, molars.

There are four different kinds of teeth on each side, both above and below. Commencing in front, these are

(*a*) *Two incisors*, each of which has a sharp cutting edge, and only one fang.

(*b*) *One canine*, with a conical-pointed crown and one fang.

(*c*) *Two bicuspids*, or as they are sometimes called *premolars*, having somewhat flattened crowns and single fangs.

Three molars, or *grinders;* these are the *true*
having broad crowns, and two or three fangs

pper surfaces of the molars and bicuspids are

---

he microscopic structure of the teeth, see chapter on
. 166.

not smooth, but raised into points, or *cusps*, the bicuspids having, as their name implies, *two* and the molars *four* or *five* cusps.

Thus there are

4 incisors above and below... ... ... = 8 teeth.
2 canines „ „ ... ... = 4 „
4 bicuspids „ „ ... ... = 8 „
6 molars „ „ ... ... = 12 „
—
Making altogether a total of ... ... 32 „

A child when born has no teeth; subsequently, however, it has two sets. The first set, or *milk teeth*, gradually appear above the gums, and are all in place at about the age of two years. They are 20 in number, viz.: 8 incisors, 4 canines, and 8 grinders. The milk teeth are shed, and the second set, or *permanent teeth*, gradually take their place.

Salivary Glands. The *saliva* is a colourless, limpid, and somewhat alkaline fluid, containing a peculiar substance called *ptyalin*. It is secreted by three pairs of glands, which are named from their several positions the *parotid*, *submaxillary*, and *sublingual* glands. Besides these there are a number of smaller glands opening into the mouth by separate ducts and known as *buccal glands*.

Each *parotid* is situated just in front of the ear, upon the outer side of the lower jaw, and its duct opens into the mouth, upon the inner side of the cheek, near the second molar tooth.

The submaxillary glands are situated within and a little below the lower jaw on either side; while the *sublinguals* are more forward and nearer the middle of the tongue. The ducts of both these glands open just below the front part of the tongue.

The mouth, in common with the rest of the alimentary canal, is lined with mucous membrane, and this secretes a certain amount of fluid which becomes mixed with the secretions of the proper salivary glands.

At the back of the mouth and on either side of the uvula, are two fleshy pillars called the *fauces;* and between these, one on each side, are the glandular bodies known as the *tonsils*.

Mastication and Insalivation. The food which has been introduced into the mouth is ground down by the *teeth*. In this process, which is commonly called *mastication* or *chewing*, the teeth of the upper and lower jaws are brought together by the action of the masticating muscles, so that substances placed between the teeth are broken or crushed.

The presence of food in the mouth and the action of the mouth in mastication, have such an influence, through the nerves, upon the salivary glands as to cause their secretions to be poured out much more abundantly than usual. One of the uses of the saliva is to soften the food by macerating it; but its most important function is to change starch into dextrin, and dextrin into sugar. In this way insoluble starchy matters are rendered soluble, and therefore more capable of being absorbed and made use of by the body. The saliva does not appear to act directly upon any of the other ingredients of food; but experiments show that food mixed with saliva is much more readily digested in the stomach, than food which has been simply mixed with water.

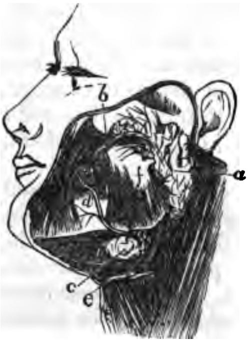

FIG. 19. Face dissected to show salivary glands: *a*, parotid gland; *b*, its duct passing forward to enter the mouth; *c*, submaxillary gland, the duct of which is not shown; *d*, is placed upon the lower jaw close to the facial artery; *e*, hyoid bone; *f*, masseter muscle, one of those used in mastication. (*Quain*.)

Swallowing or Deglutition. When the food has been sufficiently masticated, it is rolled into a *bolus*, and pushed by the tongue through the *fauces* into a kind of muscular funnel called the *pharynx*.

Just above the fauces the two nasal passages open into the pharynx by two apertures called the *posterior nares;* and below, at the back of the tongue, is another aperture termed the *glottis*, which leads into the lungs. When the food presses against the *uvula*, it tends to cover the *posterior nares*, so as to prevent the food from passing into the nasal chambers. Similarly there is immediately above the opening of the glottis, a kind of lid called the *epiglottis*, which, when the tongue presses the food through the fauces, shuts down over the glottis, and prevents any portion of the food from falling into that aperture. The *pharynx* is continued below into the muscular tube called the *œsophagus*, which is placed directly in front of the vertebral column, and passes downwards into the *stomach*. As soon as the food passes into the pharynx, the muscles of its walls are stimulated to contract, so as to constrict the tube immediately above the bolus of food. The constriction passing gradually and regularly downwards along the œsophagus, pushes the food before it until it reaches the stomach.

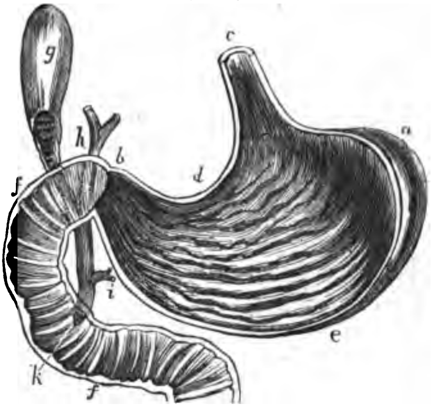

FIG. 20. View of the interior of the stomach and duodenum: *a*, cardiac dilatation; *b*, pylorus; *c*, œsophagus; *d*, lesser curvature; *e*, greater curvature; *f*, duodenum; *g*, gall-bladder; *h*, biliary duct; *i*, pancreatic duct; *k*, common opening of the bile and pancreatic ducts. The transverse folds in the duodenum are the *valvulæ conniventes*. (*Gray*.)

Stomach. The *stomach* is a somewhat conical sac, having strong muscular walls. Its upper border forms a short concave *lesser curvature;* while its lower border forms a long convex *greater curvature*. This organ is situated below the diaphragm, and is partly covered by the lobes of the liver. The œsophagus opens into the upper part of its larger or *cardiac* end, by what is termed the *cardiac orifice.* The smaller end of the stomach is continued into the intestine; the aperture of communication, called the *pylorus,* is surrounded by a collar of muscular fibres termed a *sphincter.*

The stomach is lined by a mucous membrane, which gives it a soft and velvety appearance. When not distended by food the interior is traversed by numerous longitudinal folds, and is of a pale pinkish colour. If the mucous membrane be closely examined, it will be seen to exhibit a kind of honeycombed appearance. A section through the wall of the stomach (fig. 21) shows it to be composed of three principal layers, 1st, the peritoneum; 2nd, bands of unstriped muscular fibre, arranged in several layers, and running in various directions; 3rd, the mucous membrane, in which the gastric glands are lodged.

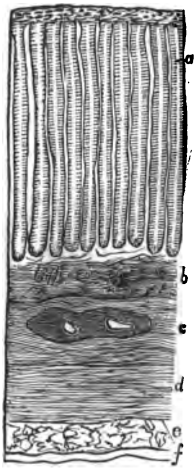

FIG. 21. Vertical section of the wall of a pig's stomach (magnified 30 diameters): *a*, gastric glands; *b*, muscular layer of mucous membrane; *c*, submucous layer; *d*, *e*, longitudinal and transverse layers of muscular fibres; *f*, serous coat. (*Kölliker.*)

Gastric Glands. A careful examination of the surface of the mucous membrane, shows that besides the honeycombed appearance there are great numbers of minute pores. These are the openings of the *gastric glands* which are shown in section in fig. 21. The gastric glands are of two kinds. (1) Those situated near the pylorus, which are lined, quite to their inner ends, with a layer of *columnar epithelium* (p. 159), they are long straight tubes, which at their inner ends may be simple, as in fig. 21, or divided into several branches. As they are supposed to secrete mucus only, they are called *mucous glands.* (2) In other parts of the stomach the glands are only partly lined with columnar epithelium, the inner portions being filled with irregular cells (fig. 22). It is these which secrete the proper *gastric juice;* and as this fluid contains the peculiar substance called *pepsin*, they are termed *peptic glands.*

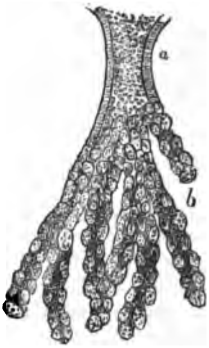

Fig. 22. A peptic gland, from cardiac portion of human stomach (magnified 50 diameters): *a*, cylindrical epithelial cells; *b*, spherical secreting cells. (*Kölliker.*)

Beside the glands already mentioned, there are found scattered over the surface of the interior of the stomach a large number of small sac-like glands called the *lenticular follicles.*

All these glands are surrounded by a network of bloodvessels.

Gastric Juice and its Action upon Food. When the stomach is empty its walls are of a pale tint, and there is no proper gastric fluid secreted. Directly food is introduced, a nervous action is set up which causes the bloodvessels to become more distended with blood, and the *gastric juice* is then secreted, and commences to act upon the food. This juice is a distinctly acid fluid, the acidity being due to the presence of free *hydrochloric acid.* But the most important constituent of the gastric juice is *pepsin*, which is most active in dissolving the proteids of the food. Both the acid and the pepsin are necessary for proper digestion.

The gastric juice has the power of dissolving the nitrogenous constituents of the food, but has no direct action upon the fatty or starchy matters. The acid which it contains neutralizes the alkali of the saliva, and stops the action of the ptyalin, so that in the presence of gastric juice, starch is no longer converted into sugar.

The presence of food in the stomach causes certain contractile movements in its walls, which materially assist digestion by mixing the food more intimately with the gastric fluid.

The result of the action of the gastric fluid upon the various kinds of food is, that they are more or less completely dissolved and reduced to a thin pulp, which is then called *chyme.*

Albuminous materials undergo a very considerable change, losing some of their chief characteristics, when acted upon by *gastric juice.* For instance, albumen loses its property of coagulating by heat, and gelatin will no longer solidify when cooled; so that when dissolved in gastric juice, the albuminous principles cannot be distinguished from one another. In this condition they are all known by the one name of *peptone.*

Part of the fluid of the chyme is absorbed by the vessels of the stomach. (*Absorption*, p. 52.)

The Intestine. The *intestine* is divided into two portions, which differ considerably in diameter, and are hence termed the *small* and the *large.* The *small intestine* is continued from *the stomach*, and is in the human adult about twenty feet in length. The *large intestine* is continuous with the *small*, and is from four to six feet in length.

The Small Intestine is generally divided into three portions, but there is no definite line of demarcation between them. That portion of the intestine which immediately succeeds the stomach is termed the *duodenum.* It is about ten inches in length, bent round upon itself, and more fixed by the peritoneum than any other portion. The common duct of the liver and pancreas opens into the *duodenum. Jejunum* and *ileum* are the names given to the other two portions of this intestine.

The walls of the small intestine, like those of the stomach, consist of three layers, viz.: 1, *the mucous;* 2, the *muscular;* and 3, the *serous* or *peritoneal.*

(1) The *mucous*, or *internal layer*, is raised up into numerous transverse folds, called *valvulæ conniventes.* These are found closely set in the *duodenum* and *jejunum*, but they afterwards grow fewer in number, and cease at about the middle of the *ileum.* They serve to increase the absorbing surface of the intestine, and also prevent the more liquid products of digestion from passing down too quickly.

The villi are fine thread-like processes covering the surface of the mucous membrane of the *small intestine* like the pile of velvet. Each villus, in common with the rest of the mucous membrane of the intestine, has an outer layer of columnar epithelium. Within this is a network of blood capillaries, and occupying the centre of the villus is a single *lacteal vessel*, which is occasionally looped. (*Absorption*, p. 52.) Between the lacteal vessel and the blood capillaries, exists a delicate layer of unstriped muscular fibres.

The function of the villi is to absorb the nutritive materials from the products of digestion. The manner in which this is accomplished will be considered further on.

(2) The *muscular coat* is composed entirely of unstriped fibres (p. 168), divided into two layers. In the outer layer the fibres run longitudinally, whilst in the inner they are arranged in circles around the intestine. It is these muscular fibres which produce the peculiar movements of the intestine called *peristaltic contractions*. The manner in which this takes place is as follows:—The circular muscles contract at a certain point, and thus reduce the diameter of the intestine, the longitudinal fibres also contracting at the same part; then the fibres immediately below this point contract, and the former become relaxed, and this being continued in regular succession downwards, a constriction travels along the intestine towards the rectum. The *peristaltic movements* of the intestine can be seen if the abdomen of an animal be opened directly it is killed.

(3) The *serous layer* is that portion of the peritoneum which is reflected over and adheres closely to the outer surface of the intestine.

The Large Intestine. At the point where the large and the small intestines join, the mucous membrane is raised into a fold called the *ileo-cæcal valve*, which guards the opening of the *ileum*, and prevents the chyle passing back into the *small intestine*. At the same place there is also a pouch-like dilatation of the large intestine called the *cæcum*, and at the extremity of this is a small worm-like body termed the *vermiform appendix.*

The large intestine is divided into the *colon* and the *rectum*. The parts of the colon are named from the position they occupy, the *ascending*, *transverse*, and *descending* portions; the last of these being continued into the *rectum*, which is dilated, but again contracted at its termination.

The walls of the large intestine, like those of the small, are composed of three coats or layers. In the *cæcum* and *colon*, however, the longitudinal muscular fibres are arranged in three bands, and these being shorter than the other coats, the walls are puckered up and thrown into a kind of pockets or *sacculi*. This is not the case in the *rectum*. The *anal* aperture, like the pylorus, is surrounded by a strong ring of muscular fibres, or *sphincter*, which keeps it securely shut, except during defecation.

The Glands of the Intestine are of three kinds. 1. *Lieberkühn's glands* or *follicles*, which are simple tubular depressions of the mucous membrane. They are present in all parts of both intestines, but are largest in the large intestine, more particularly towards its termination.

2. *Peyer's glands*. These consist of an oval sacculus imbedded in the mucous membrane, and richly supplied with bloodvessels, but apparently without any aperture. They occur separately or aggregated in patches, and in the *small* intestine only, chiefly near the ileo-cæcal valve. Glands very similar to these occur in the large intestine, chiefly in the cæcum and vermiform appendix, and have been termed *lenticular glands*.

3. *Brünner's glands* are confined to the duodenum; they are minute lobulated bodies, situated in the most internal portion of the mucous layer, and opening by special ducts upon the surface.

The Liver. The *liver* is a large glandular organ, of a dark red colour, situated immediately below the diaphragm. It is the largest gland in the body, and in the adult weighs about four pounds. It has an incomplete covering of peritoneum. Its upper part is rounded, and fits into the arch formed by the diaphragm. Below, the liver is irregularly concave, and divided by deep fissures into several portions called *lobes*. It rests upon the stomach, duodenum, right kidney, and some other parts. At the hinder part and towards the right side the lobes are thick, but in front they are thinner. The chief supports of the liver are three bands of fibrous tissue, formed by the peritoneum, known as the *broad* and the two *lateral ligaments*.

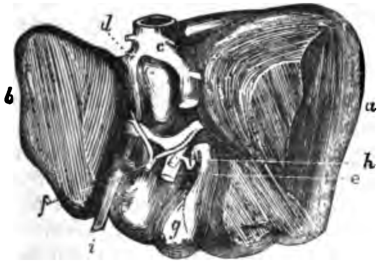

FIG. 23. The liver turned over from left to right, so as to show the under surface: *a*, right lobe; *b*, left lobe; *c*, vena cava inferior; *d*, left hepatic vein; *e*, vena portæ; *f*, hepatic artery; *g*, gall bladder; from its smaller end the cystic duct is seen passing to join the hepatic duct, *h*; *i*, the round ligament.

Each *lobe* of the liver is found upon close inspection to be formed of a great number of small bodies, called *lobules* or *acini*, about $\frac{1}{20}$ of an inch in diameter. Each *lobule* consists of an aggregation of *nucleated cells* (p. 158) called the *hepatic cells*, among which ramifies a close network of capillaries. The liver is supplied with blood from *two* sources; *first*, the *hepatic artery*, which is given off directly from the *aorta*, supplies *arterial* blood; and, *second*, the *portal vein*, brings the blood that has circulated through the vessels of the intestines, etc., which is consequently *venous*. The blood leaving the liver is collected into several vessels called the *hepatic veins*, which open into the *vena cava inferior*.

The distribution of the bloodvessels in the liver is somewhat complicated. The manner in which they enter that organ will be best understood by reference to fig. 23, which gives a view of the liver from below. The *portal vein*, *hepatic artery*, and *hepatic duct*, accompany each other in their ramification among the lobules. The *portal* vein subdivides into small branches which run between the lobules (and are therefore called *interlobular vessels*), and give off still smaller branches, which penetrate the lobules, and break up into a dense capillary network, in the meshes of which are the *hepatic cells*. These capillaries are then collected into a vessel called the *intra-lobular vein*, which occupies the centre of each lobule, and opens into one of the branches of an hepatic vein. The *hepatic artery* also sends out between the *lobules* branches which communicate with the capillary network within each *lobule*.

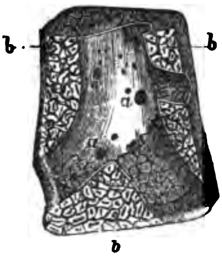

Fig. 24. Portion of pig's liver, somewhat enlarged. The section has been carried through a large hepatic vein, into which the smaller veins, *a*, are seen opening. The lobules, or acini, *b*, surround the veins.

The liver is continually secreting a fluid called *bile*, which is conveyed into the *duodenum* by a tube known as the *hepatic duct.*

When digestion is not going on the aperture by which the *hepatic duct* communicates with the duodenum is closed, and the *bile* flows into a sac called the *gall bladder*, where it is stored up until required, The gall-bladder is connected with the hepatic duct by a tube called the *cystic duct.*

The subdivisions of the *hepatic duct* have been clearly traced as far as the surface of the *lobules;* but concerning the manner in which the branches terminate, there is some diversity of opinion; probably the ultimate ramifications communicate with *spaces* between the *hepatic cells* (fig. 25). Although we may not be quite clear as to how it is accomplished, yet it is certain that the fluid secreted by the *lobules* finds its way into the *hepatic duct.*

Functions of the Liver. Besides the important function of secreting *bile*, the liver possesses the power of materially altering the condition of some of the constituents of the blood passing through it, and this results in the formation of the kind of sugar called *glucose* or *grape sugar.*

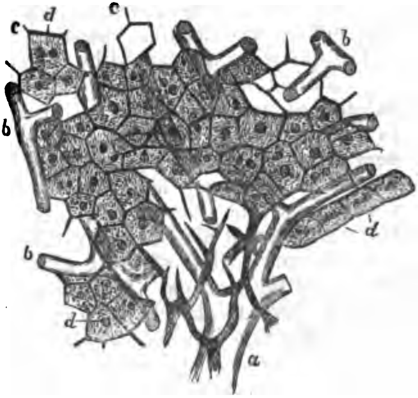

FIG. 25. A section of injected rabbit's liver, much magnified: *a*, interlobular blood-vessels; *b*, intralobular blood-capillaries; *c*, spaces between the cells which have been injected from the hepatic duct; *d*, liver cells, with nuclei. (*Klein.*)

Bile. The *bile* is a slightly alkaline, yellow fluid, with a very bitter taste. About 30 or 40 ounces are secreted daily. This secretion takes place continually, but is increased when digestion is going on. The following table will serve to show the composition of *bile*, although the proportions of the constituents vary in different examples.

OX GALL OR BILE.

Water		880·00
Glycocholate of Soda Taurocholate of Soda	Bilin	90·00
Biliverdin Bilifulvin Fat and Cholesterin	colouring matters	13·42
Mineral matters		15·24
Mucus		1·34
		1000·00

The most important of the above constituents are the *taurocholate* and *glycocholate of soda*, which form the *bilin.*

That the *bile* is derived from blood brought to the liver by the *portal vein*, and not from that brought by ıe *hepatic artery*, has been proved by experiment. Vhen the *hepatic artery* of a dog was tied so as to revent its blood passing into the liver, the bile con- nued to be secreted; but when a similar ligature was ut round the *portal vein*, the secretion of bile ceased.

Two purposes are served by the secretion of bile, viz., he elimination from the blood of certain deleterious ubstances, and the formation of a fluid which assists ı the process of digestion. The uses of the bile are ery imperfectly understood. It neutralizes the acidity f the chyme, and has the effect of reducing fatty ıatter to a fine state of division, or kind of *emulsion;* eing alkaline, it also mixes to some extent with the fats, nd so forms a kind of soap, which is very easily ab- orbed by the lacteals. It also moistens the villi, and nables them to absorb more readily. A certain por- ion of the *bile* is re-absorbed by the intestine, but it ecomes so entirely changed that it cannot be detected n the blood.

Glucose. Although no trace of saccharine matter ıay be discernible in the blood of the hepatic artery or ortal vein, yet the blood which leaves the liver by the epatic vein always contains more or less *glucose.* This as been proved in the case of animals fed entirely upon esh, where, although no sugar was taken into the ystem, yet glucose could always be found in the *hepatic ein.* The formation of glucose in the liver may be shown ı another way: take the liver from an animal just killed, nd wash out the bloodvessels by forcing water into ıe portal vein until it issues from the hepatic vein free om sugar. If now the liver be kept in a warm place r some hours, abundance of sugar will be found in it. lucose is not formed directly from the blood; but *ycogen*, an amyloid substance resembling starch, is first oduced, and then quickly changed into *glucose* by a ocess of fermentation in the blood.

Pancreas. The *pancreas*, commonly called the *sweet- ead*, is a tongue-shaped gland, of a pale cream colour. is situated behind the stomach (fig. 26), its larger end being placed in the curve of the duodenum, and its smaller in contact with the spleen. It is very similar in structure and function to the salivary glands. The small vessels conveying the pancreatic secretion from the *lobules* unite to form the single *pancreatic duct*, which generally opens into the hepatic duct near its entrance into the duodenum, but sometimes into the duodenum itself. The secretion of *pancreatic* fluid is much less constant than that of bile. It takes place chiefly during digestion, and flows into the duodenum. The pancreatic fluid when fresh is alkaline, and contains a substance called *pancreatin.* It resembles saliva, but contains no *sulphocyanide of potassium.* By it starch is converted into dextrine and sugar; and in conjunction with the *bile* it assists in converting the *chyme* into *chyle.*

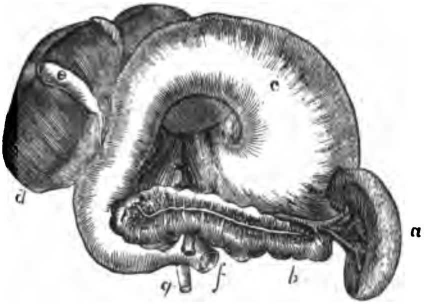

FIG. 26. View of the spleen and pancreas, the stomach and liver having been turned up so as to expose them: *a*, spleen, with its blood-vessels; *b*, pancreas, part of its surface has been removed to show its duct; *c*, under surface of stomach; *d*, liver; *e*, gall bladder; *f*, duodenum; *g*, aorta. (*Quain.*)

Intestinal Digestion. We have already seen that the starchy matters of the food are partly converted into sugar by the saliva (p. 40), and that this process is to a greater or less extent stayed in the stomach by the effect of the acid of the gastric juice upon the ptyalin (p. 43). The nitrogenous materials being acted upon by the gastric juice, are more or less dissolved, and the fatty matters are broken up, and mixed with the other constituents of the food. The fluids in the stomach and the portions of nitrogenous matter which are in a state of solution are, to a considerable extent, absorbed by the walls of the stomach.

The changes which the food undergoes in the intestines have now to be considered. The *chyme*, passing through the pylorus, enters the duodenum, and is acted upon by the *bile*, *pancreatic* juice, and by the fluids secreted by *Brünner's* and *Lieberkühn's* glands; but the precise mode in which each of these fluids acts is not known.

The most important change which the *chyme* undergoes in the intestine is that its fatty matters are so emulsified and otherwise altered as to make them easy of absorption by the villi. The alkali of the *bile* neutralizes the acid of the gastric juice, and the conversion of *starch* into *sugar* which was almost stopped in the stomach now goes on again rapidly. These changes convert the chyme into what is known as *chyle*. Nitrogenous matters also continue to be dissolved in the intestine.

The *peristaltic* movements of the intestine (p. 45), cause the chyle to move towards the lower parts of the bowel, the nutritive portions being absorbed as they pass along. It appears that most of the fatty matters find their way through the epithelium of the villi into the lacteal vessels, while the nitrogenous and saccharine constituents are absorbed chiefly by the blood capillaries of the villi.

As the chyle approaches the end of the small intestine, it becomes more and more alkaline, and most of the nutritive matters with a certain proportion of the fluids have been absorbed. But soon after passing the ileocæcal valve, it again becomes acid. This is probably due to the fermentation of some portion of the food. Absorption of the nutritive matter and fluids still goes on in the large intestine, but to a much less extent than in the small. Those portions of the food which are not digested as they pass along the intestine become more and more solid, and acquire a peculiar colour and odour; the colour being due to the colouring matters of the bile. They are then collected in the rectum, and periodically expelled.

Absorption. The manner in which the fatty portions of the *chyle* find their way through the walls of the villi into the lacteal vessels is not yet definitely known. It appears that the fatty particles in an extremely fine state of subdivision, are first absorbed by the epithelial cells of the mucous membrane, and then pass into the lacteal vessels; but how they pass from the one to the other is not known.

The absorption of solutions of sugar, albumen, etc., by the capillaries is effected by the physical process called *osmosis*. It is found that when two fluids of different densities are separated from each other only by a membrane, they pass through the membrane to each other, the one that is less dense passing through much more rapidly than the other. The passage of a less dense to a denser fluid has been termed *endosmosis;* while the passing of a denser to a less dense is known as *exosmosis*.

Hunger and Thirst. The sensation of *hunger* is felt in the region of the stomach. It does not, however, depend simply upon the condition of that organ, but arises from a want of nourishment in the tissues generally.

Nutriment introduced into the blood, without going into the stomach, relieves the sensation of hunger. Solid substances, even if they are not adapted for food, will, however, when introduced into the stomach, allay the feeling for a time.

The sensation of *thirst* is experienced apparently at the back of the mouth and fauces; but is due to a want of liquid in the blood of the system generally.

Thirst is only relieved for a very short time by moistening the fauces; but by introducing liquid into the stomach, where it may be absorbed, or directly into the blood, the sensation is completely relieved.

PRACTICAL SECTION.

Examination of the Alimentary Canal. The various parts of the alimentary canal should now be carefully examined, and the student should read the descriptions of the various organs given in the former portions of this chapter, and compare them with the parts of the rabbit.

A rabbit recently killed should be laid upon its side, and an incision made in the skin from the corner of the mouth backwards to the shoulder, and the skin turned aside and removed from the whole side of the head and lower jaw. The *parotid* gland will be found just below the ear, and the membranes, etc., which cover it should be carefully dissected off. The *submaxillary* lies below and within the jaw. The *sublingual* glands should be sought for, but they will require more careful dissection.

The lower jaw of the side being examined should now be removed: to do this, first separate, with a strong knife, its two halves at their junction in front; then cut through the muscles of the cheek and other parts by which the lower jaw is attached, and remove it from its socket. This will lay open the cavity of the mouth. The teeth will be seen to be very different from those of man. The tongue, palate, and uvula should next be examined. The animal may then be laid upon its back, and the abdomen and thorax opened as before described. There will, however, be no occasion to leave the band between the two cavities as was then done.

A wire with a rounded end should be passed down the throat until it enters the stomach, and the tube through which the wire passes (the *œsophagus*) be laid open with the knife.

The œsophagus is now cut across just below the diaphragm, and the portion attached to the stomach held with the forceps so as to raise the stomach, the mesentery being cut through to allow the stomach, with the liver and intestine, to be removed. The lower part of the rectum should be tied tightly round, and then cut through below the ligature. The stomach may be separated from the intestine, opened, and washed, and then examined with a hand-lens. The same may be done with portions of the small and large intestine, and the differences between the internal surfaces of these parts noticed.

Many of the more minute parts mentioned in the text, such as the structure of the liver and of the walls of the stomach, etc., are only to be made out by special modes of preparation and with the aid of a microscope.

Artificial Digestion. Digestion may be imitated in the following manner. Take the stomach of a newly killed rabbit, and having laid it open, scrape off the mucus from its surface, and mix it thoroughly with diluted hydrochloric acid (one part of acid to 100 of water), put the solution of *pepsin* thus formed into a bottle along with a small portion of lean meat chopped fine. Keep the liquid continually agitated at a temperature of about 100° F., and the meat will gradually dissolve. If the temperature is not kept up, the process will stop. When the bottle is allowed to stand quietly, it takes a much longer time for the meat to dissolve.

Osmosis. Tie a small glass tube tightly in the neck of a small thin bladder, and then fill the bladder with some dense fluid such as strong solution of salt. If this be now placed in a vessel containing water, the salt solution will be found to rise gradually in the tube, owing to the water passing in through the membrane faster than the salt solution passes out.

CHAPTER VI.

THE BLOOD.

Uses and Composition. The blood is the red fluid which circulates through the *arteries*, *capillaries*, and *veins*. Its uses in the system are very various and important. It carries the nutritive materials to all the tissues of the body, and the products of waste to those organs whose function it is to eliminate and discharge them from the system. From the *blood* the various secretory glands derive the materials for their secretions. The *blood* also carries to all parts of the system the oxygen it receives in the lungs. And again, it is by means of the blood that the temperature of the body is equalized. It is essential to the life of the tissues that they receive a proper supply of blood; that is to say, they must be so situated with regard to the capillaries that the nutritive matters contained in the blood, and exuding through the walls of the vessels, may get to the tissues, and that the products resulting from their waste may pass into the blood.

Although apparently a homogeneous fluid, the blood, when examined with the microscope, is seen to consist of a colourless fluid termed the *plasma*, or *liquor sanguinis*, in which are suspended great numbers of minute bodies, called the *blood corpuscles;* these are mostly of a *red* colour, but some of them are colourless, and are distinguished as the *white* or *colourless corpuscles*.

Blood is an alkaline fluid somewhat heavier than water; it varies in colour from bright scarlet to a deep purple, according to the part from whence it is obtained. That which issues from a wounded artery is bright scarlet, and is termed *arterial blood;* while that issuing from a vein when cut is purple, and is called *venous blood.**

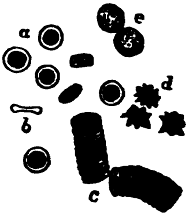

FIG. 27. Human blood corpuscles (magnified 500 diameters): *a*, red corpuscles, showing central depression; *b*, one seen edgeways; *c*, several forming into rods or rouleaux; *d*, crenulated at the margin; *e*, two colourless corpuscles.

The difference in the colour of the blood depends upon the amount of oxygen which it contains; the scarlet colour being caused by the presence of a greater quantity of oxygen, and the purple by a deficiency of oxygen. The amount of carbonic acid is always greater in venous than in arterial blood. (See *Respiration.*)

The quantity of blood in the body is said to be about $\frac{1}{10}$ or $\frac{1}{12}$ of its entire weight. The temperature of the blood is maintained very constantly at about 100° F.

Coagulation of the Blood. If blood be drawn from the body and allowed to stand quietly for a few minutes, it will be found to lose its fluidity, and become semi-solid or jelly-like. After a time the mass contracts, and a yellowish fluid called *serum* is pressed out. The solid portion, known as the *clot* or *crassamentum*, will float in the *serum*.

The change in the blood just described is called *coagulation*, and is brought about in the following manner:—It has been ascertained that the *plasma* of blood contains two peculiar substances, closely allied to *globulin* (p. 29). One of these, termed *fibrinoplastin* or *paraglobulin*, is closely allied to, if not identical with, the *globulin* of the red corpuscles. It may be obtained not only from blood plasma, but also from chyle, lymph, connective tissue, the crystalline lens, etc. The second substance, called *fibrinogen*, may be obtained from blood plasma and also from serous fluids, such as pericardial fluid, p. 15, etc. When these two substances unite a fibrous material is formed which has received the name of *fibrin*. If a small portion of coagulated blood be examined with a microscope, it will be seen to consist of a mass of these fibres in which the blood corpuscles are entangled.

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* The pulmonary *artery* yields purple blood, and the pulmonary *vein* scarlet blood; the reason of this will be obvious when th changes which the blood undergoes in the lungs are considered.

From what has just been said, it is clear that *fibrin*, as such, does not exist in fluid blood, but is the result of the combination of the two substances, fibrinogen and paraglobulin. *Fresh* blood, then, consists of *plasma* and *corpuscles; coagulated* blood of *serum*, *fibrin*, and *corpuscles;* consequently, as fibrin is derived from the plasma, it is obvious that *serum* is *plasma*, *minus the materials which form fibrin.*

Under ordinary circumstances, when blood coagulates the *fibrin* is formed before the *corpuscles*—which are slightly heavier than the *plasma*—have had time to settle down, consequently they become entangled with the fibrin. But if by any means coagulation be retarded, or the corpuscles be made to sink more rapidly, fibrin may be obtained free from corpuscles.

In cases of inflammation blood is found to coagulate much less rapidly than usual, and the coagulation presents certain peculiarities. In the first place the fibrin, being formed less quickly, the corpuscles have time to sink; they also have a greater tendency than usual to run together into rolls (p. 59), and this condition helps them to sink through the plasma more readily. Thus it is that in the *clot* of inflammatory blood the red corpuscles are only found in the lower part. The upper part has an opalescent whitish appearance, and is known as the *buffy coat.* This kind of clot contracts more than ordinary *clot*, and its surface presents in consequence a peculiar cup-like form.

Conditions which hasten Coagulation:—

1. A moderate temperature, 100° to 120° F. hastens coagulation.

2. Contact with foreign bodies. Blood allowed to flow into a vessel begins to coagulate first where it is in

ontact with the vessel. A wire thrust into a vein ecomes coated with fibrin. When drawn blood is tirred with a bundle of wires or twigs they become oated with fibrin.

3. Rest is generally favourable though not essential o coagulation.

Conditions which retard Coagulation:—

1. Cold has the effect of retarding coagulation, and it is said not to take place at all when the temperature is below 40° F.

2. Contact with living tissue keeps the blood fluid for a very considerable time; this is especially the case with living bloodvessels.

4. The addition of a sufficient quantity of many saline matters, especially *sulphate of soda,* effectually prevents coagulation; but if water be added, so as to dilute the salt, coagulation takes place.

Plasma. The constituents of blood vary in proportion in different individuals, and in the same individual at different times. On an average out of 100 parts of blood 79 are water and 21 solid matter. The plasma and corpuscles exist in very nearly equal volumes, the plasma being slightly in excess. As we have already seen, the *plasma* contains paraglobulin and fibrinogen, which are the constituents of *fibrin.* Although *fibrin* plays uch an important part in the process of coagulation, the mount of it in the blood is extremely small, 1000 parts f healthy blood yielding only from 2 to 4 of *fibrin.* The *serum,* that is, the *plasma* minus its *fibrin,* is an lkaline fluid containing about a ninth part of its weight f solid matters. *Albumen* forms about 8 per cent. of he *serum,* the remainder consisting of fatty, extractive, nd saline matters dissolved in water.

Red Blood Corpuscles. It is the *red corpuscles* which ive to the blood its characteristic colour. These bodies re soft and flexible, and have the form of round discs. n man their diameter is about $\frac{1}{3200}$ of an inch, and their hickness about $\frac{1}{10000}$ of an inch. Their surfaces are not under the microscope they exhibit a central part, which, according to circumstances, appears lighter or darker than the surrounding portion. This central part must not be confounded with the minute spot or *nucleus* found in the red blood corpuscles of some animals; for the red corpuscles of human blood have no nucleus.

The tendency of the red corpuscles to run together has been already alluded to under coagulation (p. 56). Soon after blood has been drawn, the red corpuscles become attached to each other by their flattened surfaces, forming rods or rouleaux, which join together in an irregular kind of network, a small portion of which is shown at fig. 27, *c*.

Each red corpuscle consists of a tough outer coat containing a fluid or almost fluid material of a red colour, known as *hæmoglobin*, and sometimes called *cruor*. *Hæmoglobin* may be resolved by certain processes into *globulin* and a colouring matter called *hæmatin*. The true colouring matter of blood corpuscles in its natural condition is *cruorin*, but in the process of separating it from the globulin it becomes slightly changed in character, and is then termed hæmatin. Hæmatin contains a considerable proportion of *iron*.

White Blood Corpuscles. The *white* or *colourless* corpuscles are larger and far less numerous than the red. They have a diameter of about $\frac{1}{2500}$ of an inch, and are *nucleated*; that is, they have in their interior a small rounded body or *nucleus*, which in rare cases only is red. Their great peculiarity is that while alive they are constantly changing form. Fig. 28 will give some idea of the shapes assumed. A portion of the soft material of which the corpuscle is composed, is slowly thrust out at different points, and then gradually

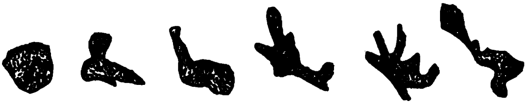

FIG. 28. Various forms assumed by a colourless blood corpuscle. (*Klein.*)

withdrawn again. In fact, these colourless corpuscles exactly resemble those low forms of animal life known as *amœbæ*, which inhabit stagnant waters.

The following table shows the constituents of blood in about their average proportions.

Blood contains	WATER				784·0
	SOLIDS	**Corpuscles**	*Hæmatin* *Globulin*		131·0
		Plasma	Fibrinogen Paraglobulin	*Fibrin*	2·2
			Albumen		70·0
			Fatty matters		1·3
			Saline matters Extractive matters		11·5
					1000·0

Gases of the Blood. It is found that 100 volumes of blood contain on an average about 40 or 50 volumes of gaseous matters. The gases are the same as those found in the atmosphere, namely, carbonic acid, oxygen and nitrogen; but the proportions in the two cases are very different.

Blood has a much greater power than pure water of absorbing oxygen. This property is apparently due to the red corpuscles. Serum alone has comparatively little power of absorbing oxygen; while the red corpuscles if suspended in pure water absorb this gas freely. A solution of hæmoglobin absorbs oxygen in a similar manner. The oxygen absorbed by the blood combines very loosely with the hæmoglobin, so that it it is very readily given up in the system when required.

Blood Crystals. Hæmoglobin under certain conditions exhibits the peculiar property of crystallizing. The crystals of human blood have a prismatic form, but are difficult to obtain. Crystals are much more easily obtained from the blood of some of the lower animals, as the *dog*, *rat*, *guinea-pig*, etc., and they are found to vary in form according to the animal.

Changes which the Blood undergoes in the Body. It has been already mentioned that the blood exists in the body, in two different conditions, viz.: *arterial* and *venous*. The most obvious difference between them is their colour, the former being bright scarlet and the latter purple. But the most important difference is in their composition. *Arterial* blood contains more *oxygen* and less *carbonic acid* than the *venous*, and somewhat more *fibrin*, and rather less *albumen* and *fat*. If venous blood be exposed to the air it soon changes colour and becomes arterialized. If, on the other hand, arterial blood be exposed to *carbonic acid* it gets darker, and becomes at length venous; but this change does not take place so rapidly as the former. The same changes take place, but more slowly, when a thin moist animal membrane intervenes between the blood and the air or carbonic acid.

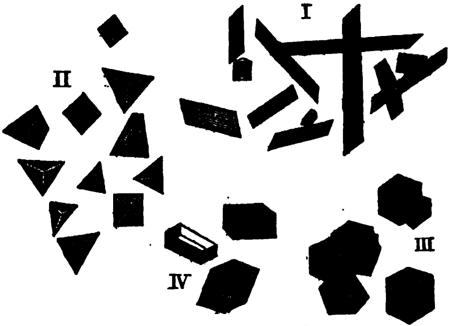

FIG. 29. Blood crystals magnified. I., from human blood; II., from guinea-pig; III., from squirrel; IV., from hamster. (*Quain.*)

The blood passing through the capillaries of the lungs is only separated from the air by a very delicate membrane (p. 78), and therefore part of the oxygen contained in the air is absorbed by the blood, and part of the carbonic acid contained in the blood passes through the membrane and becomes mixed with the air, the venous blood thus becoming arterialised. (See *Respiration.*)

Why the absorption of oxygen and the giving up of carbonic acid causes the blood to assume a bright red colour is not known with certainty. It has been thought that the red corpuscles are somewhat flattened by the presence of oxygen, and slightly swelled by carbonic acid, and that in the former case they reflect the light more strongly, and therefore give a brighter appearance to the blood. This may have some effect in producing the bright colour, but probably it is chiefly due to the fact that hæmoglobin when combined with a certain amount of oxygen is of a dark red colour, but if combined with a larger proportion of oxygen, it assumes a much brighter appearance. The quantity of carbonic acid in the blood has much less effect upon its colour than the amount of oxygen.

The conversion of arterial into venous blood takes place in the capillaries of the body generally, a considerable proportion of its oxygen being used up in the process of oxidation; the amount of oxygen used depending upon the quantity of material oxidized. The carbonic acid formed in the process of oxidation, passes through the walls of the capillaries into the current of the blood.

The composition of the venous blood in different parts of the body varies considerably: for instance that returning from the stomach and alimentary canal is more or less charged with the soluble portions of the food which have been absorbed. That issuing from the liver by the hepatic vein always contains glucose, and that returning from the spleen is usually deficient in red corpuscles, and contains an unusually large proportion of the colourless corpuscles.

PRACTICAL SECTION.

Coagulation of the Blood. This may be seen by simply allowing some freshly drawn blood to stand quietly for a short time. If one or two drops are allowed to fall upon the bottom of an inverted saucer, and then covered over with a watch glass, a piece of wet blotting paper being placed under the glass to keep the blood from drying, it will be found that the blood loses its fluidity, and becomes jelly-like. If a larger quantity be allowed to stand in a basin or other suitable vessel, the phenomena mentioned on p. 56 may be observed.

Coagulation retarded by the Addition of Salts. Make a saturated solution of *sulphate of soda*, and dilute it with an equal quantity of water. Take a wide-mouthed bottle, and put into it about one-fifth as much as it will hold of the above solution. Then fill up the bottle with *freshly drawn* blood, which may be obtained from a butcher's slaughter-house, and if possible should be got into the bottle direct from the animal. Well mix the two fluids by shaking, and then allow the mixture to stand quietly. Under these conditions the blood will not coagulate; and further, the *blood corpuscles*, being heavier than the *plasma*, will sink to the bottom, leaving the plasma as a more or less clear fluid.

When the corpuscles have sunk to the bottom of the bottle, let some of the clear fluid be carefully decanted into another vessel. To show that this fluid contains the materials necessary for coagulation, add to it about one-fifth of its volume of water. It will then be found to lose its fluidity, and to become a jelly, as in the first experiment; but being free from red corpuscles, it will be almost colourless.

Blood Corpuscles. In order to examine blood corpuscles a moderately powerful microscope is necessary. Let a small drop of blood (which may be readily obtained by pricking the finger with a sharp needle) be placed upon a clean slip of glass, and covered with a piece of thin glass, such as is ordinarily used for microscopic purposes.* By this means the blood is spread out into a film, and may be examined with the microscope. At first the corpuscles will be seen as pale disc-like bodies floating in a clear fluid. After a time they will be observed to stick to each other by their flattened faces so as to form the rows already mentioned (p. 59). The colourless corpuscles are to be seen among the red ones, but they are much less numerous. The amœba-like movements of the colourless corpuscles, which take place very slowly, are most easily studied in the blood of the *newt*. The best way to see them is to take a drop of blood from a newt just killed, and arrange it on a slip as above directed, then carefully surround the thin glass cover with a rim of oil to prevent the blood drying; get a colourless corpuscle fairly in view in the field of the microscope, and draw its form upon a piece of paper. After letting it stand quietly upon the microscope for a few minutes, draw it again, and observe the difference in its form.

The red corpuscles of newt's blood will be observed to be larger than those of human blood; to be oval and not round; and to have in their interior, a small body or *nucleus* which is not present in human red corpuscles.

The colourless corpuscles of both the human and newt's blood have a *nucleus*.

The nuclei of the blood corpuscles are better seen if a drop of magenta staining fluid (see *Appendix*) be allowed to run under the thin covering glass, as the nucleus will become more deeply stained than the rest of the corpuscle.

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* Both kinds of glass may be obtained at any shop where microscopic materials are sold

Blood Crystals. Crystals of hæmoglobin are more readily obtained from the blood of some animals than from that of others. One mode of obtaining them is the following. Let a large drop of perfectly fresh *guinea-pig's* blood fall upon a clean slip of glass, and be left to coagulate. Then add a small quantity of water, and after a short time lift the mass with the forceps, and place some small drops of the fluid upon another glass slip and allow them to evaporate, when crystals will be formed, and may be viewed with the microscope.

CHAPTER VII.

ORGANS OF CIRCULATION.

General View of the Circulation. Having considered the nature of the blood, it now becomes necessary to understand the manner in which it is distributed through the body. In order to do this it will be well *first* to notice the general course of the circulation, and *secondly*, to study more in detail the organs by which circulation is accomplished. There are two main courses in which the blood circulates, viz., the *Systemic* or *greater* circulation, and the *Pulmonary* or *lesser* circulation.

a. Systemic Circulation. Let us trace the course which the blood takes, starting say from the *left ventricle*, until it returns to that point again. On leaving the *left ventricle* the blood, which is then *arterial*, passes into the *aorta*, and thence by branches termed *systemic arteries* to all parts of the body, the branches dividing and subdividing, get smaller and smaller, until they become extremely minute and are termed the *systemic capillaries*. It is in these that the blood becomes venous, as described in the last chapter.

From the *systemic capillaries* the blood passes into the *systemic veins*, all of which communicate at length with two large vessels, the *venæ cavæ*. Through these the blood is poured into the *right auricle*, thus completing the *systemic* or *greater circulation*. All blood brought to the right auricle is *venous*. The blood then passes into the *right ventricle*.

The blood returning from the alimentary canal, is collected into a vessel called the *vena portæ*, which, entering the liver, divides and subdivides until it forms a meshwork of capillaries. After passing through these *capillaries* the blood is again collected, this time into the *hepatic veins* which open into the *inferior vena cava*. This passage of the blood through the liver is known as the *portal circulation*.

b. Pulmonary Circulation. From the *right ventricle* the blood flows into the *pulmonary artery*, whose branches open into the capillaries of the lungs. In passing through these *pulmonary capillaries* the blood becomes arterialized. It is then received into the *pulmonary veins*, and conveyed by them into the *left auricle* of the heart. From thence it passes into the *left ventricle*, the point from which we supposed it to start, and so completes the *pulmonary* or *lesser circulation*.

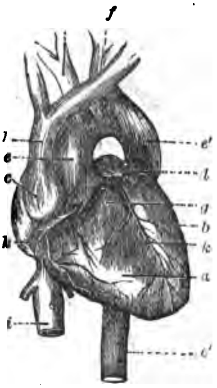


FIG. 30. Front view of the heart and great vessels: *a*, right ventricle; *b*, left ventricle; *c*, right auricle; *d*, left auricle; *e*, aorta; *e'*, *e'*, its descending portion; *f*, arteries arising from the arch of the aorta; *g*, base of pulmonary artery, the upper part having been cut away; *h*, superior, and *i*, inferior, vena cava; *k*, *k*, coronary arteries. (*Quain.*)

The Heart. The heart, as we have seen, is the central organ of the circulatory system. It is by means of its powerful contractions that the blood is driven to all parts of the body. In size the heart is about equal to the closed fist of the person to whom it belongs. It is placed in the thorax, between the lungs, but not quite in the middle line, its base being turned upwards and backwards, and its apex downwards and forwards, reaching to the space between the fifth and sixth ribs, a little to the left of the sternum.

It has already been stated that the heart contains four chambers. The *right auricle* opens freely into the *right ventricle*, and the *left auricle* opens freely into the *left ventricle;* but the chambers on the one side do not communicate directly with those on the other.

The heart is a muscular organ, all the muscles being of the striped kind, but their fibres are destitute of sarcolemma. (See *Histology*.) The walls of the two auricles are thin, having simply to drive the blood into the ventricles. The walls of the *ventricles*, in accordance with the much greater work they have to perform, are thick, those of the left ventricle being much thicker than those of the right; the right ventricle having to drive the blood through the lungs only, while the left has to force it throughout the entire body.

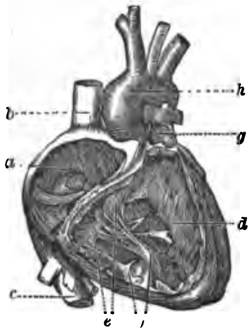


FIG. 31. View of the right side of the heart. Part of the walls of the right auricle and ventricle have been cut away to show the interior: *a*, interior of right auricle; *b*, superior, and *c*, inferior vena cava; *d*, interior of the right ventricle; *e*, tricuspid valve, the borders of which are attached to *f*, one of the columnæ carneæ; *g*, points to an aperture made in the pulmonary artery, below which two of the semilunar valves are seen; *h*, the aorta. (*Quain.*)

Externally the heart is covered by one layer of the *pericardium*, and internally by a membranous and epithelial lining called the *endocardium.*

The heart itself is supplied with blood, by the two *coronary arteries* which are given off from the aorta just above the semilunar valves; these arteries, dividing and subdividing, convey blood to the tissues of the heart, from which it is returned to the one *coronary vein*, which opens directly into the *right auricle.*

Vessels connected with the Heart. The *right auricle* has three vessels opening into it: the *superior* and the *inferior venœ cavœ*, and the small *coronary vein.* The *left auricle* receives the four *pulmonary veins.* The *right ventricle* gives off the *pulmonary artery*, and the *left* gives off the *aorta.*

The Valves of the Heart and Arteries. Each auricle opens freely into the ventricle on the same side of the heart, the aperture being guarded by certain membranous folds or *valves.* These valves are supported upon a fibrous ring surrounding the auriculo-ventricular aperture, and project inwards and downwards, forming flaps whose inner edges are connected either by slender tendinous cords (*chordæ tendineæ*) with pillar-like elevations of the walls of the ventricles, termed *papillary muscles,* or with certain little muscular pillars (*columnæ carneæ*) rising from the walls of the ventricles.

The result of this arrangement is that the pressure of the blood in the auricle acting upon the upper surface of the valves causes them to fall back against the walls of the ventricle, thus leaving the aperture open. But when the ventricle contracts, the blood getting behind the flaps forces them upwards, and causes them to meet together across the aperture, effectually closing it. The chordæ tendineæ prevent the edges of the valves from being carried into the auricles by the pressure of the blood.

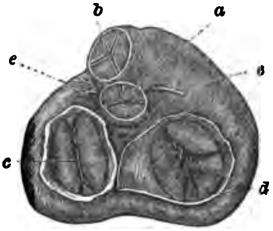


FIG. 32. View of the heart from above, the auricles and arteries having been removed: *a,* commencement of aorta with its three semilunar valves; *b,* base of pulmonary artery, with its three semilunar valves; c, left auriculo-ventricular aperture and bicuspid valve; *d,* right auriculo-ventricular aperture and tricuspid valve; *e, e,* coronary arteries. (*Quain.*)

The *right* auriculo-ventricular aperture is guarded by three of these flaps, which together form what is known as the *tricuspid valve.* The valve of the *left* auriculo-ventricular aperture has only two flaps, and from its resemblance to a bishop's mitre, is called the *mitral valve.* It is sometimes termed the *bicuspid.*

The aperture between the left ventricle and the aorta, and that between the right ventricle and the pulmonary artery, are each strengthened by a fibrous ring supporting three pouch-like valves which allow the blood to pass out of the ventricles, but completely close the aperture against its return. These valves, which are in both cases called *semilunar valves*, are the only ones found in the *arteries*.

Valves of the Veins. At the point where the inferior vena cava opens into the *right* auricle there is a membranous fold termed the *Eustachian valve;* and many of the veins of the body have at intervals in their course folds of the lining membrane so placed as in some measure to prevent the blood passing in any direction but towards the heart.

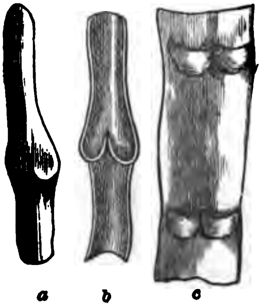


FIG. 33. Valves of veins: *a*, external view of vein distended with blood; *b*, section of similar vein showing valves; *c*, vein laid open to show pouch-like form of valves. (*Quain.*)

Beating of the Heart. The muscular fibres of the heart are so disposed, that when they contract the cavities of the heart are very much reduced in size. The contractions take place in a regular and definite manner: first, simultaneously the two auricles contract; then immediately afterwards the two ventricles; after which there is a pause before the contractions are repeated. The state of contraction whether of an auricle or ventricle is termed its *systole*, and their state of relaxation during which they dilate, is termed their *diastole*. The heart's action is not under the influence of the will, but is altogether *involuntary*. At the same time, certain affections of the mind have a considerable effect upon it.

The Nerves of the Heart. The heart is supplied with three kinds of nerves: first, it receives branches from the *pneumogastric nerve* (p. 110); second, from the *sympathetic system;* and, thirdly, it has nerves which are connected with ganglia situated in the heart itself.

The regular rhythmical contractions of the heart appear to depend upon the last set of nerves.

Certain emotions, such as those of great joy or sorrow, acting through the other sets of nerves, very materially interfere with the regular action of the heart. Thus it appears that when the sympathetic nerves are unduly excited, the beating is accelerated, inducing what is called *palpitation* of the heart. If, on the other hand, the pneumogastric nerves are affected, the heart's action is retarded, producing *fainting;* or it may be stopped entirely, and thus cause *sudden death.*

The Effect of the Heart's Contraction. All the bloodvessels being full, let us suppose the auricles also to be just filled with blood. A contraction of both auricles takes place, the tendency of which is to force their contents into the veins and into the ventricles. The veins, being already full, offer considerable resistance; but the ventricles are at this time in a relaxed condition (their diastole), therefore the blood passes freely into them.

The systole (contraction) of the ventricles follows, as we have seen, directly after that of the auricles. The effect of this would be to force the blood back into the auricles but for the *mitral* and *tricuspid* valves, which effectually prevent it. The other outlets from the *ventricles* are the *aorta* from the left, and the *pulmonary artery* from the right. Both these vessels are full of blood, and consequently oppose considerable resistance to the introduction of more; besides which, their semilunar valves are closed. But the force with which the ventricles contract is so great that the semilunar valves are forced open, and the blood is driven into both those arterial trunks.

The systole of the ventricles being completed, their walls relax, and their chambers are ready for the repetition of the process above described; the semilunar valves preventing the blood from passing back into the dilated ventricles.

Sounds of the Heart. If the ear be applied to the thorax of a living person in the region of the heart, certain sounds can be heard. First, there is a dull sound, somewhat prolonged; then follows a sharp, quick sound, and then a pause, after which the sounds are repeated. This succession of sounds is heard at every beat of the heart.

The cause of the first sound is not exactly known, but it is probably due chiefly to the closing of the *auriculo-ventricular* valves, and partly to the contraction of the muscles of the heart itself. The second, sharper sound is known by experiment to be caused by the sudden closing of the semilunar valves; for when these valves are tied so as to prevent their closing, the sound is no longer heard.

The Structure of the Bloodvessels. It will now be necessary, in order to understand certain of the phenomena presented by the circulation, to consider the structure of the *arteries*, *veins*, and *capillaries*.

If the wall of a large artery be examined, it will be found to consist of several layers. (*a*) There is first, an epithelial lining (see *Histology*), which presents a smooth surface for the blood to flow over. (*b*) Then there are several layers of a highly elastic tissue, alternating with layers of unstriped muscular fibres which are wrapped round the vessel. It will presently be seen that the elastic tissue of these larger arteries plays a very important part in the circulation of the blood. (*c*) On the outside of the arteries is a coating of fibrous or connective tissue. In the small arteries the muscular layer is proportionally thicker than in the large ones, but the amount of elastic tissue gets relatively less. The muscular fibres, which are under the influence of the sympathetic nerves, regulate the supply of blood to the various organs and tissues.

The large veins differ from the large arteries in having walls which are very much thinner, and which contain much less muscular fibre and elastic tissue. The smallest veins and arteries more closely resemble each other in these respects. Veins further differ from arteries in having certain valvular folds of membrane which are not found in the arteries.

The fine threadlike vessels called capillaries, connecting the arteries with the veins, form a delicate meshwork which traverses almost all the tissues of the body. They are from $\frac{1}{3000}$ to $\frac{1}{1500}$ of an inch in diameter. In the lungs they are even smaller than this. The meshes which they form vary much in size and character in different situations. The walls of these capillaries are composed of an extremely thin structureless membrane, in which small oval nuclei occur at intervals. The thinness of the walls of the capillaries allows the fluids they contain to exude through them for the nourishment of the adjacent tissues.

The Pulse. If the finger be placed upon an artery (the radial artery, for instance, which passes along the wrist just below the thumb), a regular rise and fall, called the *pulse*, will be felt. The cause of the pulse is as follows: When the ventricle of the heart contracts, the blood is forced into the arteries faster than it can pass through them; and as their walls are elastic they expand. This expansion does not take place throughout the body at the same time; but commences in the arteries next the heart, and gradually passes along them with a wave-like movement, which becomes less and less as it advances, until in the capillaries it ceases altogether, the blood flowing there in a continuous stream. One of the results of this onward movement of the dilatation is, that the pulse occurs in arteries near the heart before it does in those which are more remote.

There is no true pulse in the *veins;* but in the larger venous trunks there is sometimes a kind of backward pulsation from the heart.

If an artery be cut, the blood will issue in jerks. This is caused in the same manner as the pulse; the force which would be expended in dilating the vessel were it entire, is expended in driving out the blood.

Blushing and Pallor. What is commonly known as *blushing* is entirely due to the fact that the part affected has a larger supply of blood than usual, and consequently becomes red and hot. Pallor is produced by lack of blood. We have already seen that muscular fibres surround the arteries; and it is obvious that if these fibres contract the calibre of the vessel will be lessened, and that if they relax the calibre of the vessel will be increased.

Now under ordinary circumstances the *sympathetic nerves*, which are distributed to these muscular fibres, keep them slightly contracted. But under certain mental emotions, pleasurable or otherwise, the action of the sympathetic nerves is partly suspended. The result is, that the muscles become relaxed, thereby increasing the capacity of the small arteries; consequently a greater quantity of blood passes through them, and the part of the body to which they are distributed, receiving an unusual supply, becomes hot and red, or in other words is said to blush. Blushing, which is usually confined to the cheeks, may extend to other parts of the body.

Pallor may be caused by extreme terror. It is produced in a manner exactly the opposite of that by which blushing is brought about.

In pallor the *sympathetic nerve* is thrown into a state of greater activity. This causes the muscles of the small arteries to contract more than usual; consequently less blood can pass through them, and the face, which is the part usually most affected, becomes pale and cold.

The fact that these changes are due to the influence of the *sympathetic nerve* can be shown by experiment.

Evidence of Circulation. The structure of the heart and bloodvessels is such as to leave no doubt that the blood circulates in the direction described, for the valves of the heart and vessels would not allow it to flow in any other direction.

When an artery is tied in a living animal, pulsations take place only on the side of the ligature nearest the heart, thus showing that the force which produces the pulse comes from that direction. If an artery thus tied be cut on the side of the ligature furthest from the heart, as a rule, little or no blood will flow out; but if it be cut on the side nearest the heart the blood will gush out rapidly and in jerks, proving that the direction of the current of blood in the arteries is *from* the heart.

If a vein be tied it will swell up on the side of the ligature furthest from the heart, while on the side nearest the heart it will become more or less emptied.

The most direct evidence of circulation is obtained in some of the lower animals, in which the vessels traversing a thin membrane may be examined with a microscope while the animal is alive. The web between the toes of the frog's foot is perhaps the most easily observed. In it the blood corpuscles may be seen with the greatest distinctness coursing through the arteries, capillaries, and veins. (See *Practical Section.*)

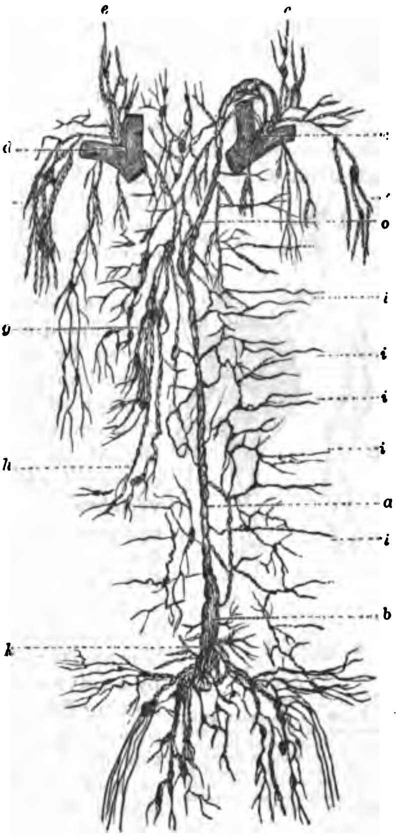
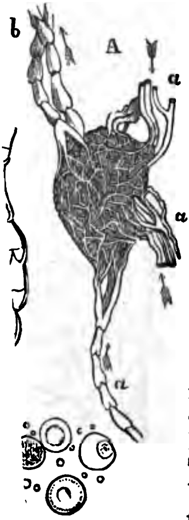


Fig. 34. Thoracic duct and lymphatics: *a*, *a*, thoracic duct, at lower end of which is *b*, receptacle of the chyle; *c*, opening of thoracic duct into the junction of left subclavian and jugular veins; *d*, junction of right subclavian and jugular veins; *e*. lymphatics of neck; *f*, of arms; *g*, *h*, of thoracic organs and diaphragm; *i*, intercostals; *k*, two short trunks which receive the lacteal vessels from intestines, and a large portion of the lymphatics from the abdominal organs. At the lower part of the figure some of the lymphatics of the lower extremities are seen. (*Quain.*)

Lymphatic System. Besides the bloodvessels just considered, the body possesses another set of vessels known as the *lymphatics*. These commence in a kind of network found in almost all parts of the body where blood capillaries exist. They have not at present been dected either in the brain, spinal cord, eyeball, gristles, tendons. This *network* differs from the blood capilries in only communicating with vessels carrying fluid *om* it.

The walls of the lymphatic vessels, although very in, are similar in structure to those of veins. They e composed of muscular fibre and elastic tissue, and e lined with epithelium. They also possess numerous valves, which are mostly in pairs and give to the vessels a knotted appearance (fig. 35). Lymphatics differ from veins in being much more uniform in size, and in being interrupted at many points of their course by certain rounded bodies termed *lymphatic glands.*

Most of the lymphatics empty their contents into the *thoracic duct* (fig. 35), a vessel about the size of a crowquill, which runs up inside the vertebral column, and terminates by opening into the venous system at the point where the vein coming from the left arm (*left subclavian vein*) joins the vein coming from the left side of the neck (*left jugular*). The aperture at this point is guarded by a valve which prevents any blood flowing from the veins into the *thoracic duct.* The remaining lymphatics unite and open in a similar manner into the veins on the right side of the body.



A, lymphatic gland *a, a, a,* vessels conuph to the gland; *b,* nveying it away; *B,* tic vessel opened to of valves; *C,* lymph magnified 400 diame-*shall.*)

entering a *lymphatic gland* the lymphatic vessels divided, forming a network of capillaries, which in united in the vessels which leave the gland.

ymphatic glands are richly supplied with bloodbut these do not communicate directly with the ics.

Lacteals. This is only another name for the *lymphatics* of the intestines. The small vessels occupying the interior of the *villi* of the intestines, are the terminations of the *lacteals* (p. 45). The trunks of these *lymphatics* or *lacteals* traverse the *mesentery* as they pass from the intestine to join the *thoracic duct*, and the *lymphatic glands* which are found upon them at this part are termed *mesenteric glands.*

The lower, enlarged portion of the *thoracic duct* which receives the lacteals is termed the *receptacle* or *cistern* of the *chyle.*

Lymph. The fluid found in the lymphatics, and termed lymph, is *alkaline* and contains nucleated corpuscles. It is in fact similar to blood in composition, except that the red corpuscles are absent and it contains a larger proportion of water. The *chyle* when absorbed from the intestine contains granules, but not *nucleated corpuscles.* The latter are only found in it after it has passed through some of the lymphatic glands. It is in these glands that the process of converting chyle into blood appears to commence, for after passing through them, the fluid contains not only corpuscles but fibrin, and will coagulate spontaneously. Lymph corpuscles have the same structure as the colourless corpuscles of the blood.

Lymph is constantly being absorbed by the lymphatic capillaries, and, eventually poured into the venous system. The quantity of this fluid thus added to the blood daily is probably about equal to the total quantity of blood in the body. Lymph consists partly of the *chyle* absorbed by the lacteals, but chiefly of blood *plasma,* which has exuded through the walls of the blood capillaries, and not having been again absorbed by the bloodvessels proper, is taken up by the lymphatics.

PRACTICAL SECTION.

Dissection of a Sheep's Heart. It is best to obtain a sheep's heart with the lungs attached, as the position of the heart will be better understood than if it be cut away from its surroundings.

Let the lungs be laid upon a dish so that the heart is uppermost, with its apex turned towards the operator.

The line of fat which extends from the upper and left side of the heart* downwards and across towards the right side, indicates the division between the right and left ventricles. Examine the large vessels, and by reference to figure 30 make quite certain which are the *aorta*, the *pulmonary artery*, the *superior* and *inferior venæ cavæ*, and the *pulmonary veins.* It will be of service to attach threads with numbers to the vessels, so that they may be distinguished when separated from the surrounding parts.

Having separated the heart from the lungs, cut out a portion of the wall of the right ventricle towards its lower part, so as to lay the cavity open. Gradually enlarge the aperture until the *chordæ tendineæ* and the membranous flaps of the *tricuspid valve* are seen. Continue to lay open the ventricle towards the pulmonary artery until the *semilunar valves* come into view. The pulmonary artery may now be opened from above so as to display the upper surfaces of the semilunar valves. Remove part of the wall of the right auricle, and examine the right auriculo-ventricular aperture; notice also the entrance of the *venæ cavæ* and *coronary vein.*

The heart may now be turned over, and the *left ventricle* laid open in a similar manner. Notice that the auriculo-ventricular valve of this side (*the mitral*) has only two flaps. The form of the valves is better seen if they are placed under water and allowed to float out. Observe that the walls of the *left* ventricle are much thicker than those of the *right.* Open the left auricle, and observe the entrance of the *pulmonary veins*, and the passage into the ventricle.

The ventricular cavity should now be opened up as far as the aorta, and the semilunar valves examined. Cut open the aorta, and notice the form of the *semilunar valves* and the openings of the *coronary arteries.*

Circulation in a Frog's Foot. In order to see the blood circulating in the membrane of a frog's foot, it is necessary to fix the frog. For this purpose obtain a piece of soft deal, about six inches long and three wide, and half an inch thick. At about two inches from one end of this cut out a hole three quarters of an inch in diameter, and cover it with a piece of glass, which should be let into the wood so as to be level with the surface. Then tie up the frog in a wet cloth, leaving one of the hind legs outside. Next fasten a piece of cotton to each of the two longest toes, but not too tightly or the circulation will be stopped. Tie the frog upon the board in such a way that the foot will just come over the glass in the aperture. Pull carefully the pieces of cotton attached to the toes so as to spread out the membrane between

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* The left side of the heart will be to the right hand of the observer, and the right side to his left hand.

them over the glass. Fasten the threads by drawing them into notches cut in the sides of the board. The board should now be fixed by elastic bands, or by any other convenient means, upon the stage of the microscope, so as to bring the membrane of the foot under the object glass. The membrane should be occasionally moistened with water.

CHAPTER VIII.

RESPIRATION.

Structure of the Lungs, etc. We have already seen something of the changes undergone by the blood in passing through the lungs. We have now to consider the structure of these organs, and the manner in which their functions are performed. The essential point in respiration is to bring the blood into such relation with atmospheric air that it may obtain the oxygen which it requires, and get rid of a certain amount of its carbonic acid.

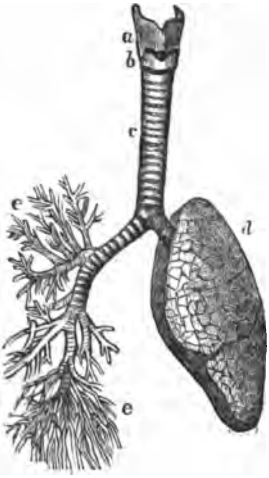

FIG. 36. Trachea and left lung: *a*, thyroid, and *b*, cricoid cartilages; *c*, trachea, dividing below into two bronchial tubes; *d*, left lung; *e*, *e*, smaller bronchial tubes of the right side, the substance of the lung having been removed.

In the front, at the lower part of the pharynx, and just at the back of the tongue, is the opening of the *glottis*, protected by its lid the *epiglottis*. Immediately within this aperture is the *larynx*, a complicated apparatus for the production of the voice, to be considered further on. Directly below the *larynx* is the *trachea*, a tube which divides at its lower end into two branches, or *bronchi*, one of which goes to each lung. Further subdivision lungs are further stretched so as to occupy the increased space. If, on the other hand, the capacity of the thorax be lessened, the lungs are compressed, or rather are allowed to shrink, and a portion of the air is driven out.

Inspiration. The enlargement of the cavity of the *thorax* may be accomplished in two ways, viz., by raising the ribs, or by lowering the diaphragm.

The manner in which the ribs are raised is peculiar. The ribs, which are movable upon the vertebral column, are directed downwards and forwards, and connected in front with the sternum by means of the costal cartilages. Between the ribs are the *intercostal* muscles, which are arranged in two sets, the one external, the other internal. The former pass from the rib above, downwards and forwards to the one next below, while the latter pass from above downwards and backwards. When the *external* intercostal muscles contract, the ribs are drawn upwards, and the sternum is raised and carried forward, increasing the distance between it and the vertebral column. At the same time, by the contraction of these muscles, the arch of each rib is raised, and the width of the chest increased. The *internal* intercostal muscles have just the opposite effect; that is to say, when they contract they draw the ribs down, and thus reduce the size of the cavity. The muscles placed between the costal cartilages tend to raise the ribs.

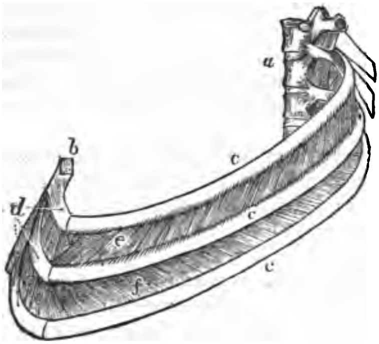

FIG. 33. Side view of three ribs, to show the intercostal muscles: *a*, vertebræ; *b*, sternum; *c*, ribs; *d*, costal cartilages; *e*, external intercostal muscles; *f*, internal intercostals, the external muscles having been dissected away.

For further explanation of the action of the intercostal muscles, see p. 86.

The *diaphragm* (fig. 16), is a strong, arched partition between the thorax and the abdomen. It is always convex above and concave below. From the central portion, which is tendinous, muscles extend towards the ribs and spine.

The action of the diaphragm is easily understood. It is obvious that when its muscles contract the arch will be drawn downwards, and consequently the cavity of the thorax will be enlarged. When the diaphragm contracts a pressure is exerted on the viscera of the abdomen which causes its front wall to be thrust out. This kind of respiration is, in consequence, termed *abdominal* or *diaphragmatic;* while that brought about by the raising of the ribs is known as *costal respiration.*

Under ordinary circumstances, both kinds of respiration take place at the same time. In men, however, the respiration is chiefly *abdominal*, while in women the *costal* is the more important.

The *diaphragm* is supplied by the *phrenic nerve*, which arises from certain of the spinal nerves of the cervical region.

Expiration. Inspiration having been accomplished by the means just indicated, the lungs and walls of the thorax are in a state of considerable tension; and in ordinary breathing, when the muscles of the ribs and diaphragm relax, the elasticity of the parts is sufficient to expel the air from the lungs. When, however, the expiratory act is to be performed with more than ordinary force, as in speaking, singing, etc., the internal intercostals come into play to depress the ribs, while the abdominal muscles by pressing upon the viscera force the diaphragm upwards, and so the air is driven out from the lungs.

Different Kinds of Respiratory Acts. *Sighing* is simply a rather prolonged inspiration.

Hiccough is an inspiratory act produced by the spasmodic action of the diaphragm; the air passing suddenly through the vocal chords (p. 154), produces the peculiar sound by which this act is accompanied.

Coughing. This consists first in a deep inspiration and closing of the glottis; then the expiratory muscles acting strongly, suddenly force open the glottis, and drive the air through the mouth.

Sneezing is very similar to coughing, but the base of the tongue and the soft palate closing the passage into the mouth, the air is expelled through the nose.

Sniffing is a short, quick, inspiratory act, in which, the mouth being closed, air is drawn up through the nose.

The effect of sudden cold upon the skin is to cause a spasmodic inspiration; for instance, if the feet are plunged into cold water a sudden drawing in of the breath takes place.

Respiration is essentially an *involuntary* action, but is nevertheless under the control of the will. All the involuntary acts of the respiratory organs are directly controlled by the *medulla oblongata.* Sneezing, coughing, hiccough, etc., are mostly involuntary respiratory movements, and are caused by what is termed *reflex nervous action* (p. 102). Sneezing, for example, is caused by an irritation of the lining of the nose. In this case certain nerves in the mucous membrane of the nasal cavity are excited, and convey an influence to the *medulla oblongata;* this part of the brain has the power of converting the influence thus received into other nervous actions which excite the respiratory muscles in such a way as to cause a violent expiratory act.

Quantity of Air Respired. It has been estimated that about 350 cubic feet of air are inspired and expired daily by an average man while at rest, the amount being very much increased during exertion.

About 20 to 30 cubic inches of air are ordinarily inspired and expired at each respiratory act.

The air thus passing in and out of the lungs is termed *tidal* or *breathing air.* After an ordinary inspiration the lungs contain about 230 cubic inches of air.

By taking a deep inspiration about 100 cubic inches more of air can be taken in; this extra amount is termed *complemental air.*

After an ordinary expiration about 200 cubic inches of air are left in the lungs, but by forcible expiration about half of this may be driven out; this is termed *supplemental* air. The lungs can never be entirely emptied of air, about 75 to 100 cubic inches always remaining; this is called *residual* air.

	Cubic inches.
Complemental air	100
Tidal "	30
Supplemental "	100
Residual "	100
Total capacity of lungs	330

The *residual* and *supplemental* air do not leave the lungs during ordinary respiration.

The number of respirations in a healthy adult vary from 14 to 18 per minute.

Changes which the Air undergoes in the Lungs. Ordinary atmospheric air consists of *oxygen* and *nitrogen* with a small amount of *carbonic acid*, *watery vapour*, and traces of other gases. Every 10,000 volumes of air contain about 7900 of nitrogen, 2100 of oxygen, and not more than 3 of carbonic acid.

If, however, air which has been *expired* be examined, the proportions of its constituents will be found to be materially altered. The carbonic acid will be found increased to about 470 parts, the oxygen reduced to 1500 or 1600 parts, the quantity of watery vapour very greatly increased, and the temperature of the air, which before entering the lungs was, say 60° F., will be found raised to about 90° or 100° F.

The amount of nitrogen in *expired* air is sometimes a little more and sometimes a little less than in air which has not been *inspired.*

Expired air thus differs from the air *inspired* in having more carbonic acid, less oxygen, more watery vapour, and a higher temperature.

The amount of carbon expired, in the form of carbonic acid, during 24 hours, is about eight ounces.

Thus it will be seen that the air in the lungs gains what the blood loses, and loses what the blood gains.

When two different gases are placed in contact they immediately begin to mix with each other, and continue to do so until they are completely mixed. This physical process is called the *diffusion of gases.* If the two gases are separated by a dry·porous partition diffusion will still take place; modified somewhat, however, by the fact that a dense gas will not pass through such partition with the same ease as a lighter one.

If the partition be a moist animal membrane the diffusion becomes still more modified, for then the gas that is most easily dissolved in water will pass through quickest. If carbonic acid be placed upon one side and oxygen upon the other, it will be found that the carbonic acid passes through quicker than the oxygen, the former being much more soluble than the latter.

These physical processes enable us in some degree to understand the changes which take place in the lungs. But they do not explain them, for although the conditions in the lungs are just those of the moist membranous partition separating oxygen from carbonic acid, yet instead of the amount of oxygen passing in being less than that of the carbonic acid which passes out, it is rather more. Why this is the case is not known; it must, however, be remembered that the oxygen (and probably the carbonic acid also) is held in chemical combination with certain constituents of the blood, and this may modify the process of diffusion.

There is another point to be borne in mind, namely, that it is the residual and supplemental air of the lungs which is directly concerned in arterializing the blood; and further that at each inspiration diffusion takes place between that and the *tidal* air.

Asphyxia. When from any cause a sufficient quantity of pure air is prevented from entering the lungs the person becomes suffocated or *asphyxiated.* In cases of strangling, drowning, or choking, the cause of death is the same, *viz.*, a want of fresh air to arterialize the blood.

The result is the same whether air is altogether prevented from entering the lungs, or whether that which is breathed has too little oxygen or too much carbonic acid. In either case the blood does not become arterialized, and *asphyxia* ensues.

Want of oxygen appears to be the most potent cause of *asphyxia*, for air may contain 15 or 20 per cent. of carbonic acid, and yet if the amount of oxygen be also increased, it can be breathed without producing any immediate ill effect.

The direct effect of want of oxygen is to retard and eventually stop the flow of blood in the capillaries of the lungs. This prevents the blood from passing out of the right ventricle, which consequently becomes gorged; as do also the right auricle, and the veins. The left side of the heart and the arteries become empty. A lack of arterial blood soon causes the heart and all the organs of the body to cease to act, and death takes place.

In small close rooms or in places where large numbers of people are assembled, and there is not sufficient ventilation, the air from being respired becomes overloaded with carbonic acid and deprived of much of its oxygen, and therefore unfit for further respiration. Persons respiring such air feel a certain uneasiness and difficulty of breathing, and the faintness which is often felt under such circumstances is a form of *asphyxia*. If such air be habitually breathed, as it is by persons who remain in close workrooms many hours daily, the blood does not become properly arterialized, consequently the organs of the body lose their vigour and are more liable to disease. A sufficient and constant supply of pure air therefore is absolutely essential to the maintenance of health.

PRACTICAL SECTION.

Examination of Lungs, etc. The cavities of the mouth and thorax of a dead rabbit having been laid open (as directed for examining the alimentary canal, p. 54), the *trachea* is traced upwards to the back of the tongue, and dissected away from the pharynx, which lies behind it. The tongue may then be cut out so as to bring the trachea with it; and, provided the upper ribs have all been cut through in opening the thorax, there will be no difficulty in separating the trachea from the surrounding parts. But the lungs and heart (which should not be severed from the trachea), are held in position by the aorta and other large vessels. These must now be cut through, in order to remove the lungs from the thorax.

The relation of the glottis and epiglottis to the tongue having been examined, the two large cartilages at the top of the trachea (the *cricoid* and *thyroid cartilages*) should be noticed. These two cartilages form the box in which the organ of voice is situated. Notice that the rings of cartilage which give rigidity to the trachea are not quite complete behind. Insert a tube into the trachea, and inflate the lungs by blowing into them. Their *elasticity* will cause them to shrink again when the blowing is discontinued. By dissecting away the substance of the lung, the *bronchi*, accompanied by the bloodvessels, may be traced for some distance; but to see the smaller vessels and capillaries, they require to be injected with some coloured fluid, and very thin slices of the lung examined with the microscope.

The Action of the Intercostal Muscles. The action of these muscles is not at first easy to understand: but it will be readily comprehended by reference to a model such as that represented in fig. 39, which may be easily made by the student himself with four laths of wood, fastened together at the corners, *a*, *b*, *c*, *d*, with pins or small screws, so as to be movable. At the points *e*, *f*, *g*, *h*, pins are placed, to which elastic bands may be attached (fig. A). *a*, *b*, represents the vertebral column; *c*, *d*, the sternum; and *a*, *d*, and *b*, *c*, the ribs. The elastic band, *f*, *g*, represents the *external* intercostal muscles, and *e*, *h*, the *internal* intercostals. If now the elastic band *e*, *h*, be removed, the remaining band *f*, *g*, will tend to bring the two points to which it is attached nearer together, and the result will be that

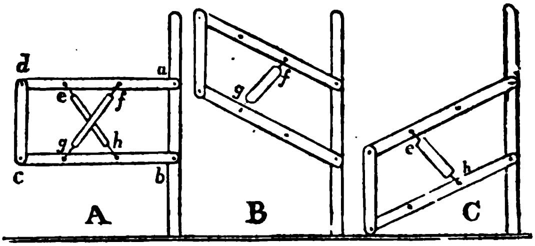

FIG. 39. Model of ribs to illustrate the action of the intercostal muscles: *B*, as in inspiration; C, as in expiration.

the bars *a*, *d*, and *b*, *c*, will be drawn upwards (fig. B), that is, in the same direction as the ribs in the act of inspiration. When the elastic band, *e*, *h*, is allowed to exert its force, the opposite effect will be produced (fig. C); in this case representing the position of the ribs in an act of expiration.

Demonstration of the presence of Carbonic Acid in Expired Air. One of the characteristic properties of *carbonic acid* is that when added to an aqueous solution of *lime*, it combines with the lime, forming *carbonate of lime*, which, being insoluble in water, becomes precipitated, and gives to the liquid a milky appearance.

Put a piece of ordinary *quick lime* into a bottle with some water; shake it, and allow it to stand until quite clear. Pour off the clear liquid (which will contain lime in solution) into a tumbler or other glass vessel; with a syringe cause ordinary atmospheric air to bubble through the liquid: little or no effect will be produced.*

Now put the end of a glass or indiarubber tube into the mouth, and allow the other end to dip into the solution of lime; let the air which is being expired bubble through the fluid. The liquid will very soon become cloudy, on account of the combination of the *carbonic acid* contained in the expired air with the lime in the solution, as mentioned above.

CHAPTER IX.

ANIMAL HEAT.

Heat not evolved in the Lungs alone. Although the heat of the body is, without doubt, dependent upon the *oxygen* supplied to the blood in the lungs, yet the process of oxidation, which is the immediate cause of the heat, takes place throughout the system.

Process of Oxidation. The internal temperature of the body is maintained at about 100° Fahrenheit, whatever may be the temperature of the surrounding atmosphere. Heat is generated wherever oxidation occurs; and whether the chemical combination takes place rapidly, as is the case in an ordinary fire, or slowly, as in the capillaries of the body, the heat generated is proportionate to the amount of material oxidized. The chief source of heat in the body is the oxidation of materials derived from the fats and amyloids taken as food; but in the capillaries of the body generally, the materials of which the tissues are composed combine with the oxygen of the blood, forming *carbonic acid*, *urea*, and *water;* and in all these processes heat is evolved.

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* The carbonic acid of the atmosphere may make the fluid somewhat cloudy.

In very cold climates it becomes necessary to supply the body with a considerable amount of readily oxidizable food, in order to maintain the requisite temperature; hence it is that the inhabitants eat and drink enormous quantities of fat and oil.

Regulation of the Temperature of the Body. Oxidation does not take place equally in all parts of the body, being more rapid in parts which are in active exercise than in those which are quiescent. The constant flow of the blood, however, equalizes the temperature by conveying heat from the warmer to the cooler parts. Without this constant circulation of warm blood, the surface of the body would be rapidly cooled by the radiation of its heat; but the continual flow of the warm fluid from deeper parts to the surface, and its quick return to the deeper parts, maintain the exterior of the body at very nearly the same temperature as the interior.

The heat of the body is further regulated in a remarkable manner. The moisture or perspiration which is constantly evaporating from the surface of the skin (pp. 24, 93), carries off a considerable amount of heat. The quantity of perspiration depends upon the condition of the small vessels and capillaries which supply the glands of the skin. If these vessels are relaxed, more blood flows through them, and consequently more perspiration is secreted and thrown out upon the skin. Now the condition of the bloodvessels is affected, through the influence of the nerves, by every change in the temperature of the medium surrounding the body. If this temperature be increased, the nerves are affected in such a manner as to allow the muscles of the vessels to relax;

the result is that more perspiration is exuded, and this in evaporating carries off the extra heat. If, on the other hand, the temperature of the surrounding medium is lowered, the nerves are affected in such a manner as to cause the small bloodvessels to contract, by which the amount of perspiration is lessened, and the loss of heat by evaporation reduced.

CHAPTER X.

SECRETION AND EXCRETION.

Definitions. There are certain organs of the body having for their function the separation of particular matters from the blood. When the matters are separated in order to be again made use of in the body, they are termed *secretions;* and the organs which subserve this purpose are called *secretory organs.* When, however, the materials are eliminated so that they may be thrown out of the system, they are called *excretions*, and the organs performing this work are termed *excretory organs.* The *secretory organs* are the *liver* and *pancreas*, *salivary*, *gastric*, *intestinal*, *lachrymal*, *Meibomian*, and *mammary glands*, and the *serous*, *synovial*, and *mucous membranes*, etc. The *excretory organs* are the *skin*, *lungs*, and *kidneys.*

Process of Secretion. The exact manner in which the various secretions are eliminated is not known; but it appears that the cells lining the gland extract from the blood certain materials by which they grow, and that the fluid they contain, which is the *secretion*, is set free by the absorption or bursting of the cell wall.

The secretion of some glands is increased if the nerves which supply them be irritated. For instance, if the nerve supplying the salivary glands be excited, the saliva is directly poured out in greater abundance. It is not known whether this effect is due to the action of the nerve upon the bloodvessels connected with the gland, causing them to dilate, and so to supply more blood to the gland, or whether it is due to the direct effect of the nerve upon the secreting tissues.

A.—SECRETORY ORGANS.

Serous Membranes. These consist of a flat expansion of epithelial cells, supported upon a basement membrane, under which are blood capillaries, surrounded by connective tissue. These parts are found in all secretory and excretory organs, however they may be modified. Such membranes line the *pericardium*, *peritoneum*, *pleuræ*, etc., and the exudation, or *secretion*, which takes place from their surfaces, keeps them constantly moist.

Synovial Membranes. These line the shut sacs called *synovial capsules*, found between the articulating surfaces of bones (p. 150), and other parts where there is considerable friction. Their secretion is termed *synovial fluid*.

Mucous Membranes. These, which are similar in structure to the two just mentioned, line the entire alimentary canal and the respiratory and urinary organs; at the apertures of the body, as upon the lips, they are continuous with the skin. The secretion of this kind of membrane is termed *mucus*.

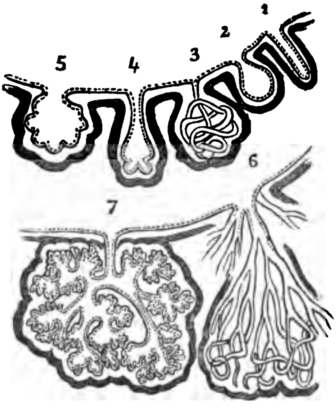

FIG. 40. Diagram to illustrate the various forms of glands: the broad dark line represents the layer of connective tissue and blood capillaries; the narrow line, the so-called basement membrane, and the dotted line the epithelium: 1, simple tubular gland; 2, saccular form: 3, a coiled tube; 4, 5, multilocular gland; 6, compound tubular gland; 7, compound saccular or racemose gland.

Secretory Glands. There are many forms of glands; the simplest consists merely of a tubular depression of the membrane, forming what is termed a *tubular gland* (fig. 40). Of this kind are the *gastric follicles* (fig. 21) and *Lieberkühn's glands*. The *sweat glands* (fig. 41) are simply tubular depressions of the skin, the inner end being coiled up. The *Meibomian follicles* in the eyelid (fig. 67) are tubular glands, the sides of which are sacculated. The *sebaceous glands*, which may be found opening into most hair sacs (p. 93), have the inner portion sacculated. The inner end of the tube may be divided into numerous branches, each ending in a little sac or *acinus*; such glands are termed *racemose*. The salivary and lachrymal glands and the pancreas belong to this last group.

The narrow tubular portion of a gland, by which its secretion is conveyed away, is termed its *duct*.

The *liver* and *pancreas* have already been described in connection with the alimentary canal (pp. 46, 50).

Ductless or Vascular Glands. The organs known by this name are certain structures usually termed glands, but whose functions are not known. None of them have any special *duct*. They are the *thyroid* gland, situated in the neck, just below the larynx; the *thymus* gland, which occupies a position at the base of the heart (this is largest in infants, and gradually disappears as age advances); the *supra-renal* capsules, placed, as their name indicates, one above each kidney; and the *spleen*. The *spleen* is a dark red body, placed in the abdominal cavity upon the left side of the stomach. It is supplied with blood by the *splenic artery;* and the vein by which the blood is carried away and poured into the vena portæ is called the *splenic vein*. The spleen is very vascular and elastic; when cut across, the surface exposed is seen to be dotted with small white bodies, called the *splenic corpuscles*, each of which is found upon close examination to be composed of very minute cells, enclosed in a network of capillaries; moreover, each *splenic corpuscle* is connected with a branch of the splenic artery. The blood of the *splenic vein* contains more white corpuscles and fewer red ones, than that of the *splenic artery*. On this account the spleen has been thought to have the function of producing colourless blood corpuscles.

B.—EXCRETORY ORGANS.

The Skin. The skin is not only an important organ of excretion, but also possesses some power of *absorption.* It is likewise the seat of the organs of *touch*, and serves as a protection to the structures lying beneath it.

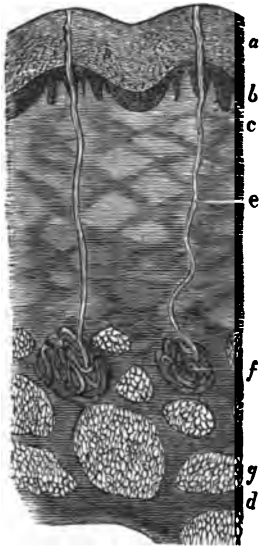

FIG. 41. A section of skin, showing sweat glands: *a*, epidermis; *b*, its deep layer; *c* to *d*, dermis or true skin; *e*, sweat duct; *f*, sweat glands; *g*, fat cells. (*Kölliker.*)

The skin consists of two portions: an outer, termed the *epidermis;* and an inner called the *dermis*, or true skin.

The epidermis is formed of layers of cells. In the exterior layers the cells are flat, but in the deeper layers they are rounder and contain the colouring matter, which gives the skin its tint.

The growth of the epidermis takes place in the deeper layers, the cells of which, becoming gradually pushed outward and flattened, supply the place of those which have been worn away from the outer surface. There are no bloodvessels in the epidermis.

The dermis, which lies immediately beneath the epidermis, differs from it in being richly supplied with bloodvessels. It is also abundantly provided with nerves. It might be expected from this conformation, that the fluids of the blood would, to a certain extent, exude through the epidermis. This in fact does take place over the whole surface of the body; but to what extent is not known, because the exudation is always mixed with the products of certain glands, of which we now come to speak.

If the palm of the hand be examined with a lens, it will be found traversed by minute parallel ridges, on the summits of which rows of small dots or pits may be seen. These dots mark the openings of the ducts of the *sudoriparous* or *sweat glands.* These consist of coiled tubes (fig. 41), surrounded by numerous capillaries, and embedded in the innermost portions of the dermis. The ducts from these glands pass through the dermis and epidermis, often spirally, and open upon the surface of the skin, the aperture being somewhat oblique and valve-like. Sweat glands are found over the whole surface of the body, but are especially numerous upon the palms of the hands.

The *sebaceous glands* are also found in the skin. They are minutely lobulated bodies, surrounded by blood capillaries, and their ducts open sometimes upon the surface, but more frequently into the sacs, or *follicles*, in which the hairs are lodged. These glands are found over the whole surface of the body, except the palms of the hands and the soles of the feet; and are most numerous on those parts where hair grows most abundantly. They secrete a fatty substance.

Ordinarily the perspiration does not collect upon the skin, but evaporates as fast as it is formed. It is then termed *insensible* perspiration. Under certain circumstances, however, as for example, after violent exercise or in cases of mental excitement, the excretions of the skin are poured out faster than they can evaporate; hence they collect in drops upon the surface of the body. This is called *sensible* perspiration, or *sweat.* Carbonic acid and water are the most important materials got rid of by the skin. The amount however varies very considerably at different times. It has been estimated that about twice as much water passes off from the skin as from the lungs, while the amount of carbonic acid is only about one-thirtieth or one-fortieth part as much.

The surface of the *dermis* is covered with minute epithelial cells, continuous with those of the mucous membrane lining the ureter and the pelvis of the kidney. It is not known with certainty whether or not the *glomerulus* has a covering of epithelium.

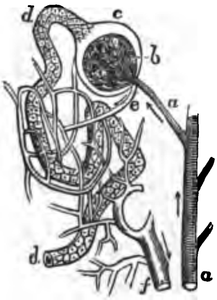

FIG. 44. Diagram showing the relation of the bloodvessels to the Malpighian bodies and uriniferous ducts; *a*, a small artery passing into *b*, the glomerulus; c, Malpighian capsule continuous with *d*, uriniferous duct; *e*, vein which conveys the blood away from the glomerulus, and joins the network of blood capillaries which surround the uriniferous tubes; *f*, branch of renal vein receiving the blood from the network.

The elimination of the urine from the blood takes place in the Malpighian capsules and in the tubuli. This process goes on constantly; and the fluid passes into the pelvis of the kidney, and thence through the ureter it enters drop by drop into the bladder.

Urine when fresh has usually an acid reaction; but if left to stand, it soon becomes alkaline. It consists of a large proportion of water, containing *urea*, *uric acid*, *animal matters*, and *saline substances*, together with very small proportions of carbonic acid, oxygen, and nitrogen. The amount excreted varies very considerably, being influenced by many circumstances. It has been estimated that a healthy man excretes about fifty ounces daily.

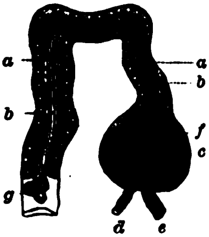

FIG. 45. Malpighian body at the end of a uriniferous tubule (partly diagrammatic): *a*, uriniferous tubule; *b*, its epithelial lining continuous with that of the Malpighian capsule, c; *d*, vein and *e*, artery of glomerulus, *f*; *g*, detached epithelial cells. (*Kölliker.*)

Supply of Blood to the Kidneys. Each renal artery arises directly from the aorta, and entering the kidney at the *hilus*, supplies it with arterialized blood. Its ultimate branches enter the Malpighian capsules as above described. The blood is collected into the *renal vein*, which, leaving the kidney also at the *hilus*, opens into the inferior vena cava. The blood does not become venous in passing through the kidney, that which passes out by the renal vein being even more pure than that which enters by the renal artery. One reason is that the urine which is eliminated from the blood in the kidney contains more carbonic acid and less oxygen than the blood itself, consequently there must of necessity be proportionally more oxygen and less carbonic acid in the blood after the urine has been excreted than there was before. Besides this, urea and other waste matters are also excreted at the same time. It has been shown that the blood of the renal vein contains less urea than that of the left side of the heart; it is, in fact, the purest blood of the body.

If the nerves which supply the walls of the small vessels of the kidneys be irritated, the excretion of urine ceases, and the blood of the renal vein becomes venous. It would seem that the irritation reduces the calibre of the small arteries, and consequently the pressure of blood in the capillaries, to a degree below that necessary for the excretion of urea and carbonic acid; while the absorption into the blood of the waste matters produced by the activity of the contracting muscles renders the blood venous.

The Bladder. The bladder itself is an oval sac, covered externally by a layer of peritoneum, and lined internally by mucous membrane. The muscular fibres, which are found in its walls in considerable quantity, are of the *unstriped* kind. The urine is collected in the bladder, and periodically expelled through a duct called the *urethra*, which opens externally. The orifice by which the urethra opens into the bladder is ordinarily kept closed by a ring of muscular fibres or *sphincter*.

PRACTICAL SECTION.

The positions of the various secretory and excretory organs have already been pointed out. Some of them, such as the liver, kidneys, etc., are large and easily found; but others, such as the gastric follicles, sweat glands, Meibomian follicles, etc., are small, and require to be specially prepared for microscopic observation. Further information regarding the methods of preparing some of the more important glands for investigation will be found in the chapter on Histology (pp. 160 and 169).

CHAPTER XI.

THE NERVOUS SYSTEM.

Functions of the Nervous System. The functions of the nervous system are to receive all sensory impressions; to govern all muscular contractions, and consequently all movements of the body; and to exercise considerable influence over the organic functions. The brain is the seat of consciousness, memory, reason, the will, and indeed of all mental operations.

Two Nervous Systems. The human body possesses two systems of nerves, (1) the *cerebro-spinal*, and (2) the *sympathetic*, which are intimately connected with each other. The first consists of the *brain* and *spinal cord* (or cerebro-spinal axis as they are sometimes called), with the nerves passing off from them; the second, of a *double chain of nervous ganglia*, connected with one another by cords of nerve fibre.

Both systems have two principal parts; viz., *nerves* and *nerve-centres.* The function of the *nerves* is simply to conduct nervous influences *to* or *from* the centres. Nerves which convey impressions *to* the centres are termed *afferent;* those which convey influences *away* from the centres are termed *efferent* nerves.

Nerve centres are composed of *nerve cells* or *ganglionic corpuscles* (p. 171) intermingled with fibres. Their function is either to perceive sensations, or to modify the *afferent* influences received so as to convert them into *efferent* impulses (p. 102). The brain alone is capable of *perceiving;* but the spinal cord and the sympathetic ganglia have, in common with the brain, power to convert afferent into efferent impulses, which conversion may take place without the intervention of the will.

The following illustrations will show the difference in action between afferent and efferent nerves.

The prick of a pin causes pain because certain *afferent* nerves, being unduly excited, convey the influence thus received to the brain, giving rise there to certain unpleasant or painful states of consciousness. But now suppose a person wishes to move his hand. Here the will influences the *efferent* nerves connected with the muscles which move the hand, causing such an impulse to be conveyed to the muscles, that they contract, the result being that the hand is moved.

A.—CEREBRO-SPINAL SYSTEM.

The Spinal Cord. The spinal cord is continued upwards into the brain, and downwards to about the second lumbar vertebra, where it becomes reduced to a fine thread termed the *filum terminale.* Nerves are given off at intervals from both sides of the cord, and pass out from the neural canal by apertures between the arches of the vertebræ, termed the *intervertebral foramina.*

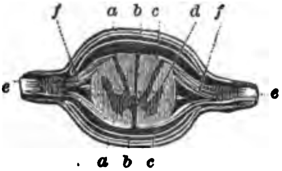

FIG. 46. Transverse section of spinal cord and its investing membranes (diagrammatic): *a.* the dura mater; *b,* outer layer, of arachnoid, which is seen to be continuous with *c,* the inner layer, thus enclosing a space; *d,* spinal cord showing anterior and posterior horns of grey substance; *e,* spinal nerve, and *f,* its posterior ganglionic root.

The membranes surrounding both the brain and spinal cord have already been described (p. 20).

The arrangement of the parts of the spinal cord is best understood by examining a transverse section. If the cord be cut through in the cervical region, it will exhibit somewhat the appearance represented on an enlarged scale in fig. 47. Two fissures, one behind, the other in front, penetrate deeply into the substance of the cord, very nearly dividing it into two lateral halves. In the middle of the isthmus joining the two halves is a small aperture, *c*, which is in fact a canal that has been cut across. It extends, as do both the *anterior* and *posterior fissures*, throughout the entire length of the spinal cord.

The section also reveals two different kinds of nerve substance; externally a white, and internally a greyish material. The white portion consists of nerve fibres running for the most part in the direction of the length of the cord, and held together by connective tissue. The grey portion contains a great number of *ganglionic corpuscles.* In each lateral half of the cord the grey inner part is so arranged as to present in section a more or less crescentic form; the extremities of the crescent being directed forwards and backwards, and termed respectively the *anterior* and *posterior cornua* or *horns.* The two crescents are connected together by a band of grey matter which passes through the isthmus (fig. 47).

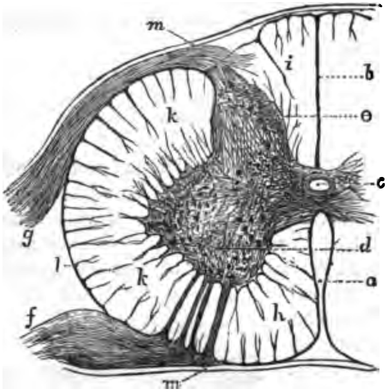

FIG. 47. Transverse section of one half of the spinal cord from the cervical region of a cat; magnified about 10 diameters: *a*, anterior fissure; *b*, posterior fissure; *c*, central canal surrounded by epithelial cells; *d*, anterior horn of grey matter; *e*, posterior horn of grey matter; *f*, anterior root of nerve; *g*, posterior root; *h*, anterior, *i*, posterior, and *k*, lateral columns of white matter; *l*, pia mater sending prolongations into the white matter; *m*, dura mater. (*From nature.*)

It will be seen by reference to the figure that the white substance in each half of the spinal cord is divided by the horns of the grey matter and by the fibres passing from these, into three portions, which have been termed the *anterior*, *posterior*, and *lateral columns.*

Spinal Nerves. Thirty-one *spinal nerves* are given off from each side of the spinal cord, and are distributed chiefly to the muscles and skin. Each nerve arises from the cord by two roots, an anterior and a posterior, both of which consist of a number of nerve fibres. The anterior root fibres arise along the line separating the anterior from the lateral column, while the posterior root fibres arise between the lateral and posterior columns(fig. 48). Just before the two roots join, the posterior root is enlarged, and forms a ganglion. Although bound up together in the same bundle, the nerve fibres of the two roots remain quite distinct, and perform two entirely different functions. It has been proved by experiment on a living animal that if the anterior root of one of the spinal nerves be cut through, the power of *motion* is entirely lost in the parts supplied by that nerve, but so long as the posterior root remains entire the parts retain their *sensibility*. If, however, the posterior root be cut and the anterior left entire, then the sensibility of the parts is destroyed, while the power of motion is retained. When both roots are severed both power of movement and sensibility of the parts are destroyed. If when both roots are cut through that portion of the anterior one connected with the spinal cord be irritated by pinching, burning, or galvanizing, no appreciable effect will be produced; but if the other portion of this same root be irritated, the muscles to which it is distributed contract. Again, if the portion of the posterior root which remains in connection with the spinal cord be irritated, it at once gives rise to the sensation of pain, but when the other portion of the same root is irritated no effect is produced.

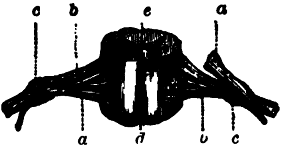

FIG. 48. Portion of spinal cord, showing origin of roots of spinal nerves: *a*, anterior root, that of the left side has been cut through and turned aside; *b*, posterior root, with its ganglion, *c*; *d*, anterior, *e*, posterior median fissure. (*Quain.*)

From this we learn that the posterior roots of the spinal nerves only convey influences *towards* the spinal cord, they are therefore *afferent* nerves; and as the influences they convey usually give rise to sensation, the nerves are also termed *sensory* nerves. The anterior roots, on the other hand, only carry influences *from* the spinal cord to the muscles, they are therefore *efferent* nerves; and as these influences cause certain muscles to contract, the nerves are termed *motor* nerves. *Afferent* nerves are not always *sensory*, neither are *efferent* nerves always *motor*.

The Function of the Spinal Cord. The spinal cord is not only the medium by which nervous influences are conveyed to and from the brain, but we shall now see that it also has the power of acting as an independent nervous centre.

The irritation of the posterior root of a spinal nerve, or of that part of the skin supplied by the nerve, immediately produces an impression upon the brain (p. 101). But if the spinal cord be cut through at any point above the exit of the nerve no sensation is felt, because the influence produced by irritation of the nerve ceases to be conveyed to the brain, which alone has the power of perceiving the sensation. Further, when the cord is thus severed the *will* has no longer any control over muscles which are supplied with nerves from the cord below the section; in other words, voluntary movement of these parts becomes impossible.

If, when the spinal cord has been cut through, we irritate any part of the body supplied with nerves from the portion of the cord severed from the brain, certain muscles connected with the separated portion of the cord will be seen to move. If the irritation be sufficiently powerful, the movements may be very violent, although no pain will be felt.

For example, if the spinal cord of an animal is severed, say in the neck, and one of the limbs be pinched, certain muscles will immediately contract and draw up the limb. These movements are altogether *involuntary*, the power of the will over them having been entirely destroyed by the section of the cord. They are due to the grey matter of the cord, which possesses the power of converting *afferent* into *efferent* impulses. That is to say the pinching causes an impulse to be carried by afferent nerves to the grey matter of the cord, by which it is again transmitted through efferent nerves to certain muscles, causing them to contract. That such movements depend upon the spinal cord is proved by the fact that when the cord is destroyed they no longer take place.

Further, afferent influences are conveyed to the cord by the posterior roots of the spinal nerves; for if these be severed while the cord is entire, the pinching of parts connected with the nerves so cut, will no longer cause muscular movements.

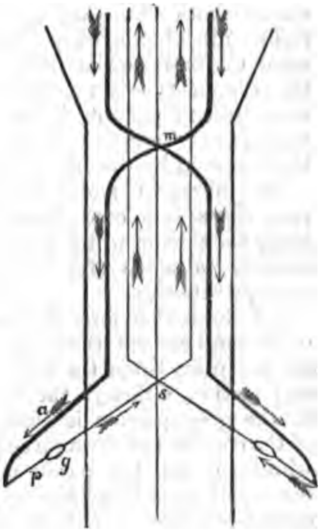

FIG. 49. Diagram to show the direction of the sensory and motor impulses in the spinal cord and medulla oblongata: *a*, anterior or motor root of spinal nerve; *p*, posterior or sensory root, with its ganglion, *g*; the crossing of the sensory fibres in the spinal cord is indicated at *s*, and the crossing of the motor fibres in the medulla is indicated at *m*; the arrows show the directions of the currents.

The peculiar power of converting *afferent* into *efferent* impulses, which we have just seen the grey matter of the cord possesses, is known as *reflex action.* It is the possession of this power that entitles the spinal cord to rank as a *nervous centre*, and not merely as a conductor of impulses to and from the brain.

The direction which the fibres of anterior and posterior roots of spinal nerves take in the cord is very peculiar. It appears that *sensory* fibres (*posterior root*), after entering the cord pass into the grey matter, and immediately cross the isthmus to the opposite side; sensory impressions being thus conveyed to the brain along the grey matter, on the side of the cord opposite to that on which they enter it.

This is shown by the following experiments. If the white matter of the cord be cut through, and the grey portion left entire,—or even though a considerable portion of the grey matter also be cut through,—sensations will still be carried to the brain. This shows that it is through the grey and not the white portion that afferent impulses pass to the brain.

Again, if the right half of the cord be cut through, including both white and grey portions, irritation of the right side of the body still produces an impression upon the brain, while irritation of the left side below the section causes no sensation. Thus showing that the sensory fibres entering upon the left side of the cord, have passed across to the opposite side, and have there been severed by the cut.

The fibres of *motor* nerves (*anterior* root) do not pass across the cord directly they enter but proceed along the side on which they enter until they reach the *medulla oblongata* (fig. 49, *m*), and then cross over to the opposite side.

It follows, therefore, that when all the white portions of the cord are cut through, as in the first experiment, all the parts below the section lose the power of voluntary motion, although their sensibility remains so long as the grey portion is continuous. If the *right* side of the cord be cut through so as to divide both grey and white portions, the power of voluntary motion will be lost in all parts below the section on that side; but not on the opposite or *left* side. The sensibility, however, of the *right* side will remain, while that of the *left* side will be lost.

Motor impulses are conveyed from the brain, through the white portion of the cord, yet all the white portion is not equally concerned in their transmission. If in the thoracic region the *anterior* half of the white matter be cut through, voluntary movements can no longer take place in parts of the body below the section. On the other hand, the division of the *posterior* half of the white matter in this region does not prevent voluntary movements.

The Brain. The human brain, when viewed from above, displays two large lateral masses. These are called the *cerebral hemispheres*, and are so large as in this view to completely cover all the other parts of the brain. They are separated by a deep *median fissure* running from front to back, and the surface of each is marked out by numerous deep depressions or *sulci*, into peculiar tracts called *convolutions* or *gyri*. Certain of the *sulci* which are found upon the sides divide each hemisphere into three portions or *lobes* called respectively the *anterior*, *middle*, and *posterior* lobes.

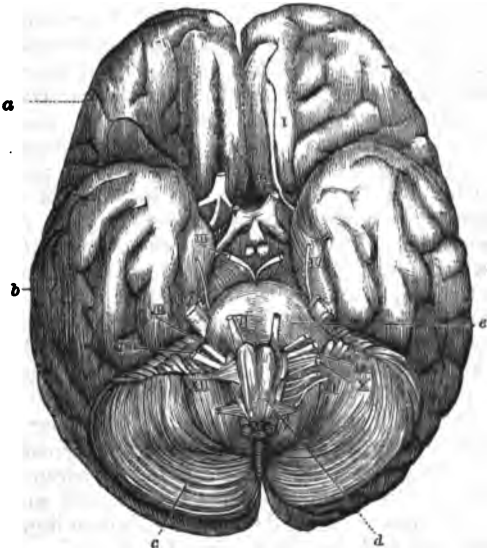

FIG. 50. Base of brain, showing the origins of cerebral nerves: *a*, the frontal lobe of the right cerebral hemisphere; *b*, the temporal lobe; *c*, cerebellum; *d*, medulla oblongata, passing into the spinal cord, which has been cut across below the first pair of cervical nerves; *e*, pons Varolii, in front of which the crura cerebri are seen; I., olfactory nerve; II., optic nerve; III., IV., VI., nerves which pass to the muscles of the eye; V., trigeminal nerve, passing out between the fibres of the pons Varolii; VII., portio dura; VIII., portio mollis, or auditory nerve; IX., glosso-pharyngeal; X., pneumogastric; XI., spinal accessory; XII., hypoglossal. Immediately behind the chiasma formed by the joining of the two optic nerves, the base of the pituitary body is seen, the body itself not being represented; and the two rounded bodies a little further back are the so-called *corpora albicantia*. (*Quain.*)

A view of the under surface of the brain is given in fig. 50. That part of the brain which is continuous with the spinal cord is the *medulla oblongata* (*d*). In it the fibres of the anterior columns of white matter (p. 104) cross from one side to the other, and at this place the columns are somewhat enlarged. These enlargements are termed the *anterior pyramids*, and the crossing of the fibres is known as the *decussation of the anterior pyramids*. Between the medulla oblongata and the posterior lobes of the cerebral hemispheres is the cerebellum (*c*). A broad transverse band of fibres called the *pons Varolii* (*e*) connects the two sides of the cerebellum. The fibres of the medulla oblongata in this view pass under the pons Varolii, and, appearing in front of it, form the two *crura cerebri*. Just in front of these there are two small rounded bodies called the *corpora albicantia*, and a little further forward the two optic nerves can be seen to join, forming what is called the *chiasma*, or *decussation*. The lobes of the cerebral hemispheres can be seen in this view, and are indicated by the letters *a*, *b*. The roman numbers in the figure refer to the cranial nerves (p. 109).

If the brain be divided longitudinally by cutting perpendicularly through all parts below the great median fissure, it will exhibit somewhat the appearance given in fig. 51. The *central canal* of the spinal cord (*i*) is continued into the medulla oblongata, where it gradually gets nearer and nearer to the dorsal surface, and at length enlarges into a chamber covered behind and above by a thin membrane, and known as the *fourth ventricle* of the brain.

The *cerebellum* (*d*) is situated above this region, and is composed of numerous plates of nerve substance, so arranged that when cut across, as in this figure, they have a foliated or tree-like appearance; on this account they have been called the *arbor vitæ*. From the fourth ventricle, a narrow canal passes upwards and forward into another cavity, the *third ventricle* (z). Above this canal are four little rounded bodies called the *corpora qua-*

drigemina (*k*); below the canal are the *crura cerebri*. The third ventricle is compressed from side to side, and is produced below into a kind of funnel connected with a peculiar little mass known as the *pituitary body* (*g*). The use of this body is unknown, and the same may be said of another small body, connected with the thin roof of this same ventricle, called the *pineal gland*. Upon each side of the front part of the third ventricle, there is an aperture (M), the *foramen of Munro*, leading into one of the two cavities found within the cerebral hemispheres, termed *lateral ventricles*.

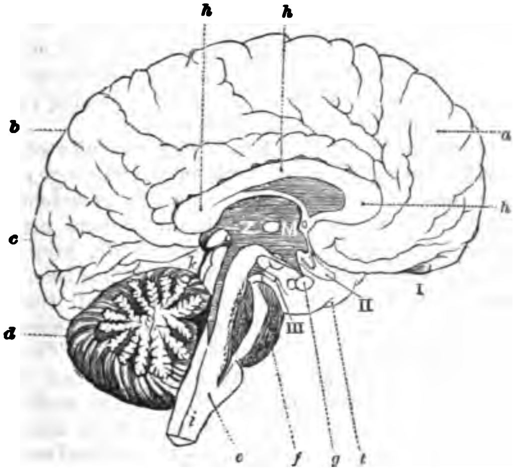

Fig. 51. Inner view of the left half of a brain which has been divided longitudinally: *a*, frontal, *b*, parietal, *c*, occipital, *t*, temporal, lobe; *d*, cerebellum, showing arbor vitæ; *e*, medulla oblongata; *f*, pons Varolii; *g*, pituitary body; *h*, corpus callosum; *i*, central canal of medulla; *k*, is placed to the left of the corpora quadrigemina; Z, is placed in the third ventricle; M, is just below the foramen of Munro, and between the anterior and middle commissures; I., II., III., first second, and third cranial nerves.

The fibres of the *crura cerebri* are continued into two nervous masses, called the *optic thalami*, which form the lateral walls of the third ventricle. From these the fibres pass into two other nervous masses termed the *corpora striata*, which form the floors of the lateral ventricles.

The *corpus callosum* (*h*) is a wide transverse band of nervous fibres connecting the two cerebral hemispheres above the third ventricle. The letter M is placed between two other transverse bundles of fibres called the *anterior* and *middle commissures*. Another small bundle of fibres, the *posterior commissure*, is placed at the back of the third ventricle.

In the medulla oblongata, the grey matter is in the interior, and the white matter on the exterior, as in the spinal cord. In the *cerebellum* and *cerebral hemispheres* this is reversed, the grey vesicular matter being external and the white fibrous portion internal.

Functions of the Brain. The *medulla oblongata* resembles the spinal cord, both in conducting nervous impressions, and also in acting as an independent nerve centre. This portion of the brain is more necessary than any other to the continuance of life, injury to it producing the most serious results. It has been shown by experiments that from some animals all the brain, except the medulla, may be gradually cut away, and life will continue for a considerable period. The spinal cord may likewise suffer extensive mutilation without producing immediate death. But if the medulla be wounded, especially near its central portion, respiration ceases, the heart stops beating, and the animal soon dies.

Mention has been made of the crossing, or *decussation*, of the motor fibres in the medulla oblongata; and we have seen how the severance of these fibres upon one side of the spinal cord below the decussation causes a loss of voluntary motion upon that side; but if the cut be made above the decussation (if for instance one of the crura cerebri be divided) the opposite side of the body is affected. This is what happens in some cases of paralysis; disease of one side of the brain causing loss of voluntary motion upon the opposite side of the body.

The regular and combined movements of ordinary respiration depend for their performance upon certain portions of the medulla oblongata.

Concerning the functions of most of the other portions of the brain, very little is definitely known. The corpora quadrigemina, with certain parts lying near them, are intimately connected with the optic nerves, and their destruction by disease or injury causes blindness.

Various functions have been attributed to the cerebellum, but at present nothing can be definitely stated, except that it exercises considerable influence in regulating and combining muscular movements.

With regard to the cerebral hemispheres, it is certain that upon them all mental operations and voluntary movements depend; any considerable derangement of these parts causing idiotcy, while extensive injury results in the entire loss both of intelligence and of voluntary motion. Endeavours have been made to show that certain portions of the hemispheres are the seat of special mental faculties, but this has yet to be proved. Experiments have lately been made which tend to show that definite regions of the hemispheres are intimately connected with the movement of special groups of muscles, but on this point further information is needed.

The brain as well as the spinal cord is capable of giving rise to reflex actions (p. 102). The closing of the eye when threatened with a blow, affords an illustration. The optic nerve in this instance acts as the afferent conductor, carrying the impression produced upon the retina to the brain, where it is reflected upon efferent nerves, and conveyed by them to the muscles that close the eyelids.

Cranial or Cerebral Nerves. From the brain and medulla oblongata twelve pairs of nerves are given off, some of which are sensory and others motor. In many anatomical works, only nine pairs are reckoned; the seventh and eighth, on account of their leaving the cavity of the skull together, being called the seventh, and the ninth, tenth, and eleventh, for the same reason, being called the eighth; the twelfth of course then becomes the ninth (fig. 50).

The first pair are the *olfactory* nerves or nerves of smell, which are really prolongations of the cerebral hemispheres. They become somewhat enlarged at their ends, and from these *bulbs*, as they are sometimes called, branches are given off to the nose. (*Sensory nerves.*)

The second pair are the *optic* nerves, or nerves of sight. These arise from the *optic thalamus* of each side, but can be traced to the corpora quadrigemina. Soon after leaving the brain, the two nerves join together in the *optic chiasma*, after leaving which each nerve passes to one of the eyes In the chiasma the fibres of the right nerve pass over to the left, and *vice versâ.* (*Sensory nerves.*)

The third pair supply all the muscles of the eyes except the two which are supplied by the fourth and sixth pairs. (*Motor nerves.*)

The fourth pair supply the superior oblique muscle of each eye. (*Motor nerves.*)

The fifth pair of nerves arise each by two roots, a sensory and a motor. Each nerve becomes divided into three branches; 1st, the *ophthalmic;* 2nd, the *superior maxillary ;* 3rd, the *inferior maxillary.* A portion of the third branch supplies the tongue, and is called the *gustatory* nerve, or nerve of taste. (*Motor and sensory.*)

The sixth pair supply the external muscle of each eye. (*Motor nerves.*)

The seventh pair supply the muscles of the face. (*Motor nerves.*)

The eighth pair are the *auditory* nerves. Each nerve terminates in the inner ear of the side to which it belongs. (*Sensory nerves.*)

When the seventh and eighth pairs of nerves are reckoned as one pair, the seventh is called the *portio dura* (hard portion), and the eighth the *portio mollis* (soft portion).

The ninth pair are called the *glossopharyngeal.* They are the nerves of taste, and are distributed to the back of the tongue and to the muscles of the pharynx. (*Sensory and motor.*)

The tenth pair, or *pneumogastric* nerves, are also known as the *par vagum.* These nerves have a wide distribution, sending branches to the lungs, larynx, stomach, liver, and heart. (*Sensory and motor.*)

The eleventh pair, or *spinal accessory* nerves, arise from the spinal cord in the thoracic region, and supply some of the muscles of the neck. They pass upwards on each side between the anterior and posterior roots of the spinal nerves, and receive fibres from the cord as they pass along to the medulla oblongata. (*Motor nerves.*)

The twelfth pair, or *hypoglossal*, supply the muscles of the tongue. (*Motor nerves.*)

All the *cranial* nerves, except the first and second pairs, may be traced to the medulla oblongata. They are called *true nerves*, while the first and second pairs, being really processes of the brain, are called *false nerves*.

B.—SYMPATHETIC SYSTEM.

Description. This system of nerves consists of a double row of ganglia, situated one on each side of the spinal column, in the thorax and abdomen, the ganglia being joined together by nervous cords into a kind of chain. Branches passing off from these ganglia connect them with the spinal nerves and with other ganglionic masses in various parts of the body. From the ganglia are given off nerves which in the main accompany the arteries, and are distributed with them to all parts of the body, but more especially to the organs contained in the thorax and abdomen.

Functions. The special functions of the sympathetic system are very difficult to determine, as many of its fibres are really derived from the spinal cord. It is certain that the actions of the heart, intestine, stomach, and some other organs, are materially affected by it. Indeed it seems probable that under ordinary circumstances the action of these organs is maintained chiefly by the influence of this system, and that the sympathetic ganglia act as centres of reflex action. At the same time the actions of all these organs are liable to considerable modification from the influence of the *cerebro-spinal* nerves which are so intimately connected with those of the *sympathetic* system.

The *vaso-motor* nerves, or nerves of the bloodvessels, belong to the sympathetic system. But many of their fibres, also, are evidently derived from the spinal nerves. The muscles of the bloodvessels are ordinarily in a state of moderate contraction, and it is found that this condition is maintained by the influence of nervous centres placed in the medulla oblongata, which are called *vaso-motor centres.*

PRACTICAL SECTION.

Brain. Directions for displaying the brain and spinal cord have already been given (p. 22). In order to examine the structure of the brain it is necessary to have it hardened. This is accomplished by placing it in spirits of wine for some days. The brain which was directed to be so preserved (p. 23) can be used for the present purpose. A sheep's brain, however, is to be preferred on account of its larger size. It may be removed from the skull in the same manner as that of the rabbit, but on account of the greater thickness and strength of the bones, it will be necessary to use stronger nippers and a saw.

The hardened brain, whether of sheep or rabbit, should first be examined entire, and compared with the description given of the human brain (p. 105), paying particular regard to the origin of each of the cranial nerves. It will be noticed that the olfactory lobes are large processes from the front of the cerebral hemispheres.

Lay the brain upon a board, insert a razor or a thin sharp knife between the two cerebral hemispheres, and divide the brain into two equal halves; examine the cut surfaces, and compare with the description of the human brain (p. 106), and with fig. 51.

The cerebral hemisphere of one half may now be cut away in successive horizontal slices, so as to expose the lateral ventricle, and to show the relation of the latter to the surrounding parts. Notice the foramen of Munro, leading from the front part of the third ventricle to the lateral ventricle.

Spinal Cord. Portions of the spinal cord, which have been hardened by being placed in chromic acid solution, may be cut across with a razor, and the cut surfaces examined. The division of the cord into white and grey portions may be distinguished in this way, but it will be best seen if very thin sections are prepared (p. 172), and examined under the microscope.

Reflex Action. The animal best suited for the study of reflex action is the frog; and in order to be quite sure that the movements which take place in the following experiments, do not depend upon the brain, the head should be completely severed from the body.

Let a frog treated in this manner be placed upon its belly, and the hind limbs extended. At first perhaps it will remain perfectly flaccid and motionless, except that the heart will continue to beat. After a time, however, the shock produced by the operation will pass off, and the limbs will be drawn up towards the body.

If the frog be now suspended by the neck, the limbs will hang down freely. Pinch the tip of one of the toes, and the limb will be suddenly drawn up to the body, and after some time gradually fall again. Stroke one side of the body with a needle. When this is done gently, only a slight movement of the muscles of the side will be observed. But if the irritation is increased the movements become more general, and at length the limbs may be caused to move.

If, while the limbs are hanging down quietly, one of the toes be touched with dilute acid, the limb will be immediately drawn up. Pinch the skin upon the inside of the thigh, the legs will kick as if endeavouring to remove the object which is irritating it. Put a drop of vinegar or dilute acid upon one of the thighs, the leg will be quickly moved about as if to rub off the acid. If, however, the leg be secured so that it cannot move, the leg of the opposite side will endeavour to rub off the acid.

To show that all the above mentioned reflex phenomena depend upon the integrity of the spinal cord, pass a blunt wire down the neural canal so as to destroy the spinal cord. It will then be found that reflex actions no longer take place.

CHAPTER XII.

SENSATIONS AND SENSORY ORGANS.

Sensations are states of consciousness, due to certain conditions of the brain, which are brought about normally by influences conveyed to that organ along particular sets of nerves. The terminal fibres of these nerves are connected with structures termed *sensory organs*, which are specially adapted to *receive* impressions, as the eyes, ears, etc. Only the brain, however, is capable of *perceiving* sensations (p. 27).

Some sensations appear to be definitely localized, while others seem more or less diffused. Of the latter kind of sensation are the feelings of *restlessness*, *uncomfortableness*, *fatigue*, and *faintness*, which cannot be assigned to any particular part of the body, and are probably due to the condition of the blood or tissues generally.

That peculiar sensation experienced in overcoming resistances, as, for example, in lifting a weight, is due to what is termed the *muscular sense.* It is this sense which enables us to judge of the relative weights of objects by poising them in the hand. It is quite a different sensation from that arising from mere contact or even from pressure. For example: when the hand is placed upon an object the sensation of *contact* is experienced, and if the hand be allowed to rest upon a table, and a heavy body be placed in the palm, the sensation of *pressure* will be felt; it is not, however, until an attempt is made to raise the hand with the object in it, that the *muscular sense* is affected, and the weight of the object perceived.

The *senses* are usually said to be five in number: viz., *touch*, *taste*, *smell*, *hearing*, and *sight*, the sensations noticed above being regarded as different kinds of touch; but as they differ somewhat from the sense of touch, properly so called, it has been thought better to mention them separately.

I. The Sense of Touch.

Organs of Touch. The sense of touch is possessed by the whole external surface of the body, by the cavity of the mouth and by the nasal passages, the degree of sensibility varying very considerably in different parts. In those parts which possess this sense in a marked degree the *dermis* is raised up into numerous *papillæ* (fig. 52), that are well supplied with blood capillaries and nerves. How the nerves terminate in the papillæ is not known. But where this sense is specially acute, as at the ends of the fingers and the tip of the tongue, many of the papillæ are found to contain peculiar rounded bodies, termed *tactile corpuscles* (fig. 52), which are connected with the terminations of the nerves.

The epidermic cells intervening between the ends of the nerve and the object felt are an essential part of the organ for touch. The necessity for this covering is shown by the fact that when it is removed by blistering or otherwise, the contact of the exposed parts with any object causes *pain*, instead of the true sensation of touch.

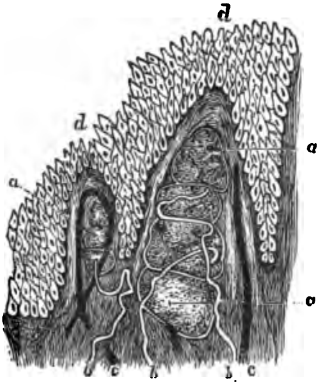

FIG. 52. Tactile corpuscles. A section through two papillæ of a finger (magnified about 300 diameters): *a*, tactile corpuscles; *b*, nerves; *c*, capillary bloodvessels; *d*, cells of the epidermis. (*Thin.*)

Nerves. The nerves of touch are derived chiefly from the posterior roots of the spinal nerves.

Acuteness of Touch. The sensibility of different parts of the body may be readily tested by means of a pair of blunt-pointed compasses. If, while the eyes are closed, the points be separated and applied to the skin, it will be found that they produce the sensation of one point, until separated to a certain distance, which varies according to the part operated upon. It has been found by this means that the tip of the tongue can distinguish the two points when only $\frac{1}{24}$ of an inch apart, the end of the finger at $\frac{1}{12}$ of an inch. Upon the cheek the points may be separated one inch and yet give rise to one sensation only; and it is said that upon the back a separation of three inches produces but a single sensation.

The sensations of heat and cold are also felt by the skin, but it appears probable that there are special sensory nerves for this purpose.

II. THE SENSE OF TASTE.

Organs of Taste. The tongue is generally called the organ of taste; but this sense is not confined to the tongue, since the soft palate and other portions of the back part of the mouth possess the same power.

The Tongue. The mucous membrane covering the tongue consists, like the skin, of two portions: an internal layer, furnished with blood vessels and nerves and an external epithelial layer. The similarity is still, further increased by the presence of numerous papillæ, supplied with blood capillaries and nerve filaments. The papillæ of the tongue are, however, peculiar in this respect, that they are of different kinds, viz.: *filiform*, *fungiform*, and *circumvallate* (fig. 53).

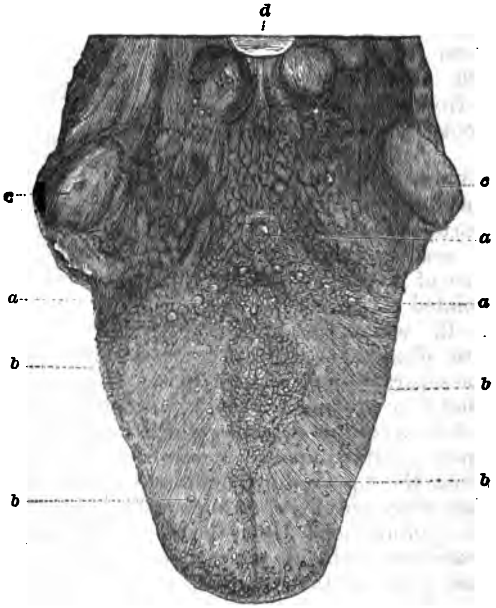

FIG. 53. Upper surface of tongue with tonsils: *a*, circumvallate papillæ; *b*, fungiform papillæ; *c*, tonsils; *d*, portion of epiglottis.

The *filiform* papillæ (fig. 54, *a*) are scattered over the whole surface of the tongue, but more especially about the middle and front. They are conical, elongated, and covered with a thick epithelium.

The *fungiform* papillæ are found chiefly upon the sides and tip of the tongue, but are also scattered over other parts. They are usually expanded at their outer extremities, whence the name.

The *circumvallate* papillæ, about eight or ten in number, are placed at the back of the tongue in the form of a V (fig. 53, *a*). They are larger than the others, and each consists of a circular elevation, surrounded by a ridge which leaves a groove or valley between itself and the papilla (fig. 54, *c*).

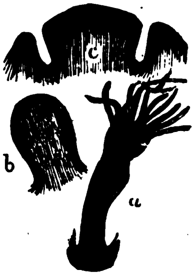

Fig. 54. Papillæ from the tongue seen in section, and enlarged: *a*, filiform; *b*, fungiform; *c*, circumvallate.

The papillæ of the tongue are called *compound* because their surfaces are covered by numerous small *secondary* papillæ, which, like those of the skin, are covered by the epithelium, and supplied with blood capillaries and nervous filaments.

In the thickness of the epithelium of some of the papillæ, and especially in the sides of the circumvallate papillæ, are to be found certain oval or pear-shaped bodies, or capsules, which are said to open upon the sur-

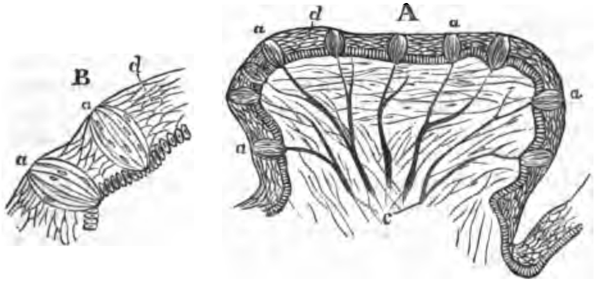

Fig. 55. A, section of circumvallate papilla of a new-born child (magnified about 50 diameters); B, a portion more magnified: *a*, the tasting goblets; *c*, lines introduced to show the probable manner in which the nerves are connected with the tasting goblets; *d*, epithelium. (*Hönigschmied.*)

face by small ducts. These capsules have been termed *taste-goblets*, and are connected with the terminations of certain nerves (fig. 55).

In order to affect the nerves of taste substances must either be taken in a state of solution or be soluble in the moisture of the mouth.

Nerves. The tongue receives sensory nerves from two sources: the posterior parts (and the back parts of the mouth) are supplied upon each side by branches from the *glosso-pharyngeal*, while the anterior part is supplied by the *lingual branch* of the *fifth* nerve.

Taste and Smell. The senses of taste and smell are frequently very intimately connected, and it is sometimes not easy to decide which of them is most affected. Many substances lose their flavour if, while they are being tasted, the nostrils are closed so that the odorous particles cannot act on the organs of smell.

III. The Sense of Smell.

Organs of Smell. Immediately within the nostrils (*anterior nares*) the nasal passages pass directly backwards, and open by the *posterior nares* into the pharynx, just above the soft palate. They are simply the lower portions of two cavities, called the *nasal chambers*, which extend upwards for some distance. These cavities are separated from each other by the partition or *septum* of the nose, which extends from the *anterior nares* upwards and backwards to the *posterior nares*. Upon the outer wall of each cavity the mucous membrane is spread over three delicate scroll-like bones, lying one above another, and known as the *superior*, *middle*, and *inferior turbinal* or *spongy* bones.

The nasal chambers are bounded below by the bones of the palate, which separate them from the mouth. They are separated from the cranial cavity above by a plate of bone, called the *cribriform plate*, which is perforated with many holes for the passage of the branches of the olfactory nerve.

Tho *organs of smell* consist of the mucous membranes lining the upper part of the two nasal chambers. These membranes are covered with columnar or cylindrical epithelium; but between the ordinary cells are to be found other much more slender nucleated bodies, termed *olfactory cells* (fig. 57). The outer extremities of these bodies terminate abruptly on a level (or nearly so) with the columnar cells; but their inner ends become much more attenuated, and are probably continuous with the nerve fibres. There is reason for believing that odoriferous particles communicate impressions to the olfactory cells, and that these transmit the impressions to the nerves.

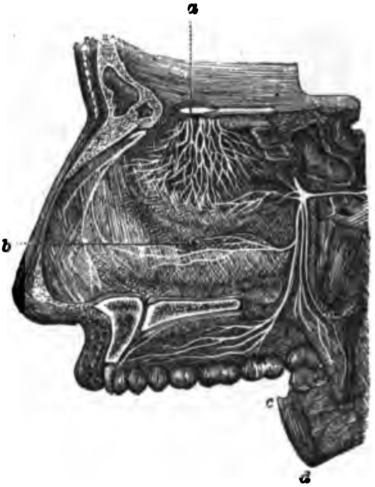

FIG. 56. Right nasal chamber, view of outer wall: *a*, olfactory lobe of brain, from which nerves are seen passing to the superior and middle turbinal bones; *b*, inferior turbinal bone; branches from the fifth cranial nerve are seen passing to the middle and inferior turbinal bones and also to the palate (above *c*); *d*, portion of lower jaw.

Nerves. That portion of the mucous membrane which covers the superior and middle turbinal bones and the upper part of the septum, is supplied with nerves from the olfactory bulb, and constitutes the true organ of smell. The nerves are of the kind known as nonmedullated (p. 171).

The lower portion, including that which covers the *inferior* turbinal bone, is supplied with branches from the fifth pair of cranial nerves. This portion of the nasal cavity is ciliated, but the upper or true olfactory portion possesses no cilia (p. 145).

Action. In order that the olfactory nerves may be affected by odoriferous matters, it seems necessary that these should be dissolved in the moisture covering the mucous membrane; for when this membrane is dry the sense of smell is more or less impaired.

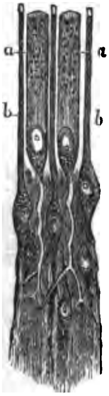

FIG. 67. Cells from the olfactory portion of one of the nasal chambers (magnified about 200 diameters): *a*, epithelial, *b*, olfactory cells.

In ordinary breathing, with the mouth closed, the air passes through the lower part of the nasal chambers, on its way to the glottis; but little or no air passes sufficiently high in the chambers to come into contact with the proper olfactory portions, and odours are only communicated to these parts by being diffused through the air which occupies the upper part of the chamber. When we wish to smell an odour more distinctly, we draw the air in at the nostrils more rapidly by the process of *sniffing*; this causes it to pass more directly upwards, and to come into contact with the upper portions of the chambers, and consequently into close relation with the olfactory nerves.

IV. THE SENSE OF HEARING.

The Structure of the Ear.—*General View.* The organs of sense hitherto considered are very simple in structure compared with those about to be described. The ear and eye are both very complicated organs, requiring careful study. They resemble the organs of smell in being double, one being placed upon each side of the head.

For convenience of description the organ of hearing is divided into three parts, viz., 1. the *External*, 2. the *Middle*, and 3. the *Internal* ear. The latter of these is the most important; and in it the auditory nerve ends. The auditory organ is lodged in the *temporal* bone, the *internal* ear being in that portion called the *petrosal* or *pars petrosa* (fig. 8, 10).

The position of the *pinna*, or what is commonly called the ear, is sufficiently well known, and the relative positions of the other parts of the auditory organ may be seen in figure 58.

1. *The External Ear.* The external ear consists of the *pinna, a*, which is chiefly composed of cartilage, and of a tube called the *external auditory meatus, b*, which passes directly inwards from the pinna; the outer portion of this tube is cartilaginous, and the inner bony. The skin which lines the external meatus is supplied towards its outer part with numerous small glands which secrete the *cerumen*, or wax of the ear.

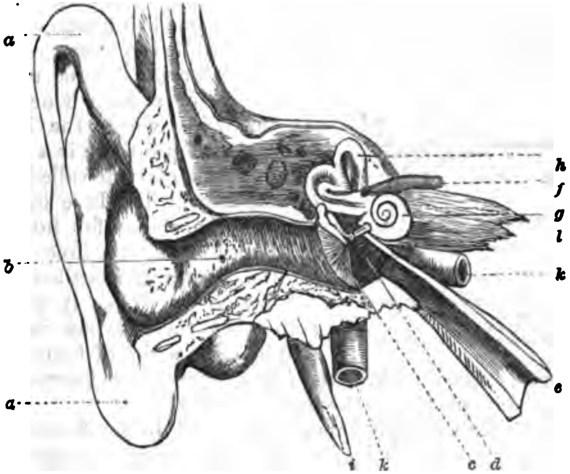

FIG. 58. Section through organ of hearing (partly diagrammatic); right side viewed from before; the bone surrounding the labyrinth has been removed: *a*, right ear; *b*, external auditory passage; *c*, tympanic membrane, above which the malleus, incus, and stapes are seen; *d*, tympanum; *e*, Eustachian tube; *f*, auditory nerve passing to labyrinth; *g*, cochlea; *h*, semicircular canal; *i*, styloid process of skull; *k*, carotid artery; *l*, petrous portion of temporal bone.

2. *The Middle Ear, or Tympanum.* The tympanum is completely separated from the external auditory meatus by a delicate membrane, called the *tympanic membrane* or *membrane of the drum* (*c*), which is stretched obliquely across its inner end. On the inner side is a small

bone called the *malleus* (fig. 59, *c*), from its supposed resemblance to a hammer; this is attached to the centre of the membrane by a process corresponding to the handle. Another and more delicate process of the malleus is called the *processus gracilis*. The head of the malleus rests upon a second small bone called the *anvil*, or *incus* (*d*). This has also two processes, the shorter one being attached to the hind wall of the tympanum, while the longer is connected with a third bone called the *stapes* or stirrup bone (*e*). At the point where the incus joins the stapes there is a very small nodule of bone called the *os orbiculare*. The base or foot plate of the stapes fits into an *oval* aperture in the inner wall of the tympanum, called the *fenestra ovalis*. Thus it will be seen that there exists in the middle ear a series of four small bones, extending from the *tympanic membrane*, across the tympanic cavity, to the *fenestra ovalis*.

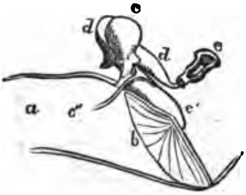

FIG. 59. Small bones of right ear, seen from before (twice their natural size): *a*, external auditory passage; *b*, tympanic membrane or drum; *c*, head of malleus, *c'*, its handle. *c''*, its processus gracilis. (*Quain.*)

The plate of the stapes is fastened to the borders of the *fenestra ovalis* by a membrane, so that this aperture which leads into the internal ear is completely closed. Just below this is another orifice, aptly termed the *fenestra rotunda*, also closed by a membrane.

The front part of the *tympanum* communicates with the upper part of the pharynx by means of a wide canal called the *Eustachian tube* (fig. 58); both this and the tympanum itself are lined by a ciliated mucous membrane.

Two small muscles must here be mentioned. The first passes from the floor of the tympanum to the orbicular bone, and is called the *stapedius*. By its contraction it increases the tension of the membrane of the fenestra ovalis. The second, called the *tensor tympani*, is attached to the malleus and the front wall of the tympanum, this serving to tighten the membrane of the drum.

3. *The Internal Ear, or Labyrinth.* Immediately within the fenestra ovalis a small chamber, called the *vestibule*,

is hollowed out of the petrosal bone (fig. 60). Communicating with it are *three* semicircular canals (also hollowed out of the same bone) whose ends open into the vestibule. On account of their positions they have received the names of *anterior* and *posterior vertical*, and *external horizontal*, *semicircular* canals. One end of each becomes dilated just before entering the vestibule, the dilatation being termed the *ampulla*.

The vestibule and canals are known as the *bony labyrinth* in order to distinguish them from the *membranous labyrinth* now to be considered. Within the vestibule is a membranous bag, the *vestibular sac*, consisting of two parts, termed the *sacculus hemisphericus* and the *utriculus*, which are separated by a thin membrane. Into the latter portion open three *membranous* semicircular canals, which lie in the bony canals already mentioned; each has a dilatation, or *ampulla*, corresponding to the dilatation of the bony canal.

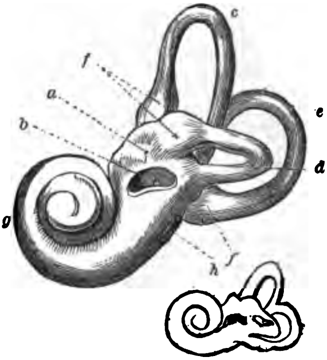

FIG. 60. Left bony labyrinth separated from surrounding bone, outer side: *a*, vestibule; *b*, fenestra ovalis; *c*, superior, *d*, horizontal or external, and *e*, posterior, semicircular canals; *f*, their ampullæ; *g*, cochlea; *h*, fenestra rotunda. The lower figure is the natural size.

The vestibular sac and its semicircular canals do not quite fill the bony cavities in which they are lodged, and the space left is filled by a watery fluid called the *perilymph*. The sac itself and the membranous canals are filled with a very similar fluid, termed the *endolymph*.

Within each membranous ampulla is a transverse ridge bearing *hair-like* processes, which are prolongations of the epithelial cells. The vestibular sac contains similar but less prominent ridges, with few or no hairs; in their place, however, are found minute calcareous particles, termed *otolithes* or *otoconia*.

Communicating with the front of the vestibule is

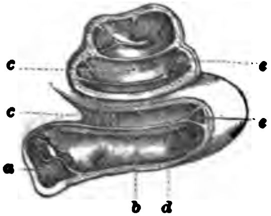

Fig. 61.

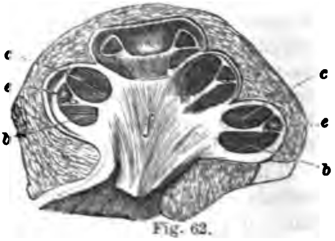

FIG. 61. Cochlea of a child laid open.

FIG. 62. Section through the cochlea and surrounding bone of a very young calf: *a*, fenestra rotunda; *b*, scala tympani; *c*, scala vestibuli; *d*, lamina spiralis; *e*, canalis cochleæ, or scala media; *f*, modiolus, in which the radiating lines represent the fibres of the auditory nerve passing to the lamina spiralis.

another peculiar canal, also hollowed out of the bone. It is coiled upon itself about two and a half times in the form of a snailshell, and has on this account received the name of the *cochlea*. The portion of bone which occupies the inside of the coil is termed the *modiolus* (fig. 62, *f*). The interior of the spiral tube is divided throughout its length by a partition called the *lamina spiralis* (fig. 61, *d*) into two portions called *scalæ*. That edge of the partition which joins the modiolus is bony, but the outer part is membranous, and has a very complex structure. The *scala* upon one side of the *lamina spiralis* opens freely into the bony vestibule, and is therefore called the *scala vestibuli*; while that upon the other side of the partition, being only separated by the membrane of the *fenestra rotunda* from the *tympanum*, is called the *scala tympani*. These two *scalæ* communicate with each other at the summit of the cochlea, at which point the *lamina spiralis* is wanting, and both are, as might be expected from their free communication with the vestibule (not the vestibular sac), filled with *perilymph*.

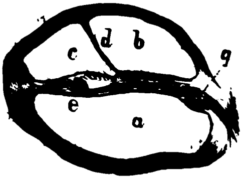

FIG. 63. Section through one coil of the cochlea, magnified about 20 diameters: *a*, scala tympani; *b*, scala vestibuli; *c*, scala media; *d*, membrane of Reissner; above the letter *e*, is the basilar membrane in which are the rods of Corti; from the nervous ganglion, *g*, nerves are seen passing in the bony lamina spiralis to the basilar membrane. (*Quain.*)

By reference to figure 63 it will be seen that the membrane of the outer part of the *lamina spiralis* separates into two portions, the space between forming a triangular canal (the *scala media*, *c*), which extends from the base of the cochlea, throughout the length of the lamina spiralis, and terminates with it near the summit of the cochlea. The upper end of this scala is closed, while the lower end opens into the vestibular sac by a small duct. The membrane which separates the *scala media* from the *scala vestibuli*, is known as the *membrane of Reissner* (*d*), while that which separates the *scala media* from the *scala tympani* is termed the *basilar membrane*(*e*). The latter structure is very elastic, and the arrangement of its parts is peculiar, as may be seen by reference to figure 64, which represents a transverse section very much enlarged. Upon that side which is directed towards the scala media, is placed a vast num-

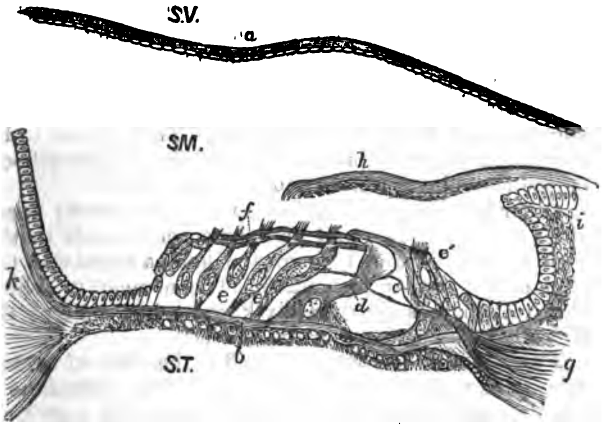

Fig. 64. Section through the scala media, including both the basilar and Reissner's membrane, magnified 400 diameters: S.V., scala vestibuli; S.T., scala tympani; S.M., scala media; *a*, Reissner's membrane, with its epithelial cells; *b*, basilar membrane; *c*, *d*, inner and outer rods of Corti; *e*, *e*, hair cells, from which hairs are seen projecting through the reticular membrane *f*; *g*, cochlea nerve, from which fibres are seen passing to two of the hair cells; *h*, membrana tectoria; *i*, crista spiralis; *k*, spiral ligament. (*Turner.*)

ber of minute rod-like bodies, the *fibres of Corti*, each of which consists of two portions joined at an angle (*c*, *d*). Upon the inner side of the Cortian fibres (that is, towards the modiolus, there is a row of cells which are provided with hairlike bodies at one extremity; one of these *hair-cells* is shown at *e′*. Outside the Cortian fibres there are several rows of similar cells (*e*, *e*). The membrane (*f*) which stretches over the hair-cells is known as the reticular membrane, and has perforations through which the hairs of the hair-cells project. Another membrane which passes outwards from the *crista spiralis* (*i*) is called the *membrana tectoria* (*h*). When the surface of the reticular membrane is viewed, the cells and *fibres of Corti* are seen to be arranged in an extremely regular manner side by side, somewhat like the keys of a piano.

Nerves. Branches of the *auditory* nerve pass to each ampulla, and to the vestibular sac. They appear to be connected with the epithelial cells in the neighbourhood of the hair-like processes and of the otolithes.

Other branches are distributed to the cochlea; these enter the modiolus, and pass by special canals in the bone through it and through the lamina spiralis to the edge of the basilar membrane. The manner in which they terminate is not certainly known; but some of the fibres have been traced to the hair-cell.

Functions of the Ear. Sound is the effect of certain vibrations upon the auditory nerves. The vibrations of a body communicate wave-like motions to the surrounding media, and in this way sound travels. A body sounding in air throws this elastic medium into a state of vibration, producing a series of aërial waves. It is found that stretched membranes take up these vibrations from the air with very great readiness.

Sound waves may be conveyed to the auditory nerves in three ways:—

First. By impinging upon the outer surface of the skull. In this case the vibrations would probably be almost lost before reaching the auditory nerve.

Second. By impinging upon the pinna or concha of the ear and being conveyed through its substance and that of the walls of the external meatus to the tympanic membrane; and thence, in a manner to be presently described, to the auditory nerves.

Third. By entering the external auditory meatus, and impinging upon the tympanic membrane, thereby causing it to vibrate. There can be no doubt that the latter is by far the most important mode in which the vibrations are transmitted to the nerves.

Sound-waves striking upon the tympanic membrane, cause it to vibrate, that is to move in and out with every wave. This motion is communicated to the malleus, and thence in turn to the incus and stapes; so that as the tympanic membrane vibrates, the stapes moves in and out of the fenestra ovalis.

The vibrations of the tympanic membrane are also conducted by the *air* in the tympanic cavity, and the sound waves consequently impinge upon the inner wall of the tympanum and upon the membranes of the fenestræ ovalis and rotunda.

The extent to which the membranes of the ear will vibrate must depend upon the tightness with which they are stretched. Now the *stapedius* muscle, when it contracts, tends, as we have seen (p.122), to tighten the membrane of the fenestra ovalis; while the contraction of the *tensor tympani* muscle tightens the tympanic membrane. The vibrations of the membranes are therefore controlled by the contraction and relaxation of these two muscles.

The vibration of the membranes of the fenestræ ovalis and rotunda causes a vibration in the perilymph of the bony labyrinth and cochlea; from which the vibrations are transmitted to the endolymph of the membranous labyrinth and scala media. Finally the *otolithes* and *fibres of Corti*, set in motion by the vibrating endolymph, so stimulate the filaments of the auditory nerve as to cause them to convey to the brain the impression which we call sound.

It has been thought that it is by means of the membranous labyrinth that we receive impressions of the varying intensity of sounds, while the cochlea enables us to discriminate between sounds of different pitch.

It is well known that a tuning fork will commence vibrating if its own particular note be sounded near to it. It has been supposed that the *fibres of Corti* are each tuned, as it were, to a different pitch, and that when a musical note is sounded, the vibrations being conveyed to the *scala media*, affect only that particular *fibre of Corti* which is tuned in unison with the note. According to this view every musical sound picks out a particular Cortian fibre and sets it vibrating, the vibrations influencing the nerve filament connected with it, so as to give rise, in the brain, to the impression of that particular sound.

The Eustachian tube appears to serve the purpose of keeping the air inside the tympanum at about the same tension as that outside.

V. THE SENSE OF SIGHT.

The Eye or Organ of Vision. *Structure of the Eye.* We have now to consider the apparatus by which impressions of light are received and converted into influences capable of affecting the brain so as to give rise to the sensation of light.

The *eyes* are two globular bodies, lodged in two cavities in the front of the skull, which are termed orbits, and surrounded by certain appendages serving for their proper adjustment and protection.

The *eyeball* is a hollow body nearly spherical in shape, of a whitish colour, and opaque, except in front, where it is transparent. Cutting it open, it is found to consist of three coats, termed respectively the *sclerotic*, the *choroid*, and the *retina* (fig. 65). The first is the external coat, the last is a fine meshwork of nerves, etc., lining the back and sides of the interior. Immediately beneath the transparent portion, or *cornea*, is a space filled with watery fluid, called the *aqueous humour*. Next comes a comparatively dense lens-shaped mass called the *crystalline lens*, behind which, and occupying the greater cavity of the ball, is the *vitreous humour*, less dense than the crystalline lens and more so than the aqueous humour.

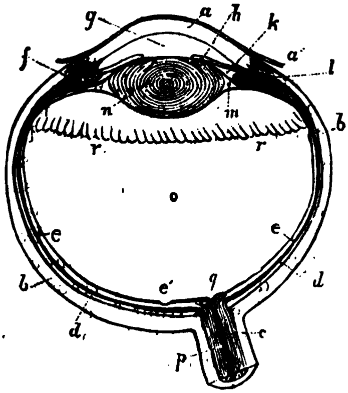

FIG. 65. Horizontal section of the left eye, view on the lower half, somewhat enlarged: *a*, cornea; *a'*, conjunctiva; *b*, sclerotic, continuous with *c*, sheath of optic nerve; *d*, choroid, consisting of two layers; *e*, retina; *e'*, macula lutea; *f*, ciliary process; *g*, chamber containing aqueous humour; *h*, iris; *k*, small chamber behind the iris; *l*, ciliary muscle; *m*, canal of Petit, a space between the suspensory ligament; *n*, crystalline lens; *o*, large chamber of the eye, containing the vitreous humour; *p*, artery in centre of optic nerve; *q*, opposite the blind spot; *r*, orra serrata at commencement of ciliary part of retina. (*Quain.*)

The Sclerotic. The white, shining outside coat or sclerotic (fig. 65, *b*) is composed of very tough fibrous tissue, that is continued into the transparent *cornea*. The cornea has a somewhat deeper curve than the rest of the eyeball, and consequently projects a little beyond the general surface.

The Choroid. On the inside of the sclerotic is the *choroid coat* (*d*); this consists of two portions, a vascular membrane which lies next to the sclerotic, and a layer of polygonal cells containing a quantity of brown or black pigment. This coat extends over the whole of the interior of the sclerotic, but just before reaching the edge of the cornea it is raised into a number of radiating folds termed the *ciliary processes* (*f*).

The Iris. Immediately within the cornea is the small chamber (*g*) filled with *aqueous humour*. At the back of this chamber is the *iris* (*h*), a kind of muscular curtain, the colour of which varies in different individuals. In the centre of the iris is the *pupil* of the eye, which is simply an aperture through which the light passes. The iris is composed of connective and elastic tissues, with bloodvessels, nerves, and unstriped muscular fibres. Some of the latter are arranged in a circle around the pupil, while others are placed radially. Coloured pigment cells exist throughout its substance; but the inner surface is covered by a layer of dark pigment cells continuous with those of the choroid. The iris is attached at its circumference to the cornea and to the ciliary processes of the choroid.

The Crystalline Lens. Behind the iris, between the *aqueous* and *vitreous* humours, is the *crystalline lens* (*n*): a doubly-convex, transparent, elastic, colourless body, having its front face curved less deeply than the back. It refracts light more strongly than either the vitreous or aqueous humours.

The lens is composed of peculiar *fibres*, arranged in a very complex manner. When hardened by boiling or otherwise, its substance may be peeled off in a series of layers, like the coats of an onion.

The lens is contained in an elastic *capsule*, and is held in position by what is called the *suspensory ligament.* This ligament is attached all round to the front and border of the capsule; and passing outwards is also connected with the ciliary processes of the choroid.

The Ciliary Muscle. Between the sclerotic and the ciliary processes are to be seen certain unstriped muscular fibres. These form the *ciliary muscle* (*l*). They are attached to the sclerotic near its junction with the cornea, and passing backwards, are inserted into the choroid; so that when they contract the choroid is drawn forward, and when they relax the elasticity of the choroid causes it to resume its former position.

The Retina. At the back of the eyeball and a little towards its inner side, the optic nerve pierces the sclerotic and choroid coats, and then spreads out to form the *retina* (*e*), which is a delicate nervous membrane, extending over the inner surface of the eye between the *vitreous humour* and *choroid*, and reaching nearly to the ciliary processes.

The Yellow Spot, or *Macula Lutea.* When a perfectly fresh human eye is cut across so as to separate it into anterior and posterior halves, there is seen in the latter, nearly opposite to the centre of the lens, an elliptical yellowish spot, the *macula lutea* (*e′*); this is the part of the retina most sensitive to light. In the middle of the macula lutea is a small depression, termed the *fovea centralis.*

The Blind Spot. On the inner side of the yellow spot, and some little distance from it, is the point at which the optic nerve enters the eye. Bloodvessels may be seen radiating from this point over the retina. This spot, being altogether insensible to light is called the *blind spot* (*q*).

Microscopic Structure. The *retina*, although apparently a simple membrane, is nevertheless a very complicated structure; but in order to see this, it is necessary to make exceedingly thin sections perpendicular to its surface, and to examine them with a powerful microscope (p. 173). A portion of such a section is represented diagrammatically in fig. 66, and will be seen to consist of a series of layers of fibres, granules, and cells.

It should be noticed that the layer (*a*) is the surface which naturally lies next to the choroid coat, and that marked (*i*) nearest to the vitreous humour.

The layer (*a*) consists of a great number of minute cylindrical bodies arranged perpendicularly to the surface of the retina; these are called *the rods;* among them are other bodies somewhat pyriform in shape, which are termed *the cones* (*b*). The *outer granular layer* (*c*) contains a number of granules, some of which are attached to the bases of the *rods and cones.* Nerve-fibres pass from the granules and probably form the layer of interwoven fibres (*d*); nerve-fibres also pass from this interlaced portion to the *inner granular layer* (*e*). The layer of *fine convoluted* nerve-fibres (*f*) is connected with the inner granular and with the ganglionic corpuscles (*g*). The connective tissue which naturally lies among the convoluted fibres, appears to contain numbers of molecules, and hence this layer has been termed the *molecular* *layer.* At *h* is seen the layer of nerve-fibres spread out from the optic nerve.

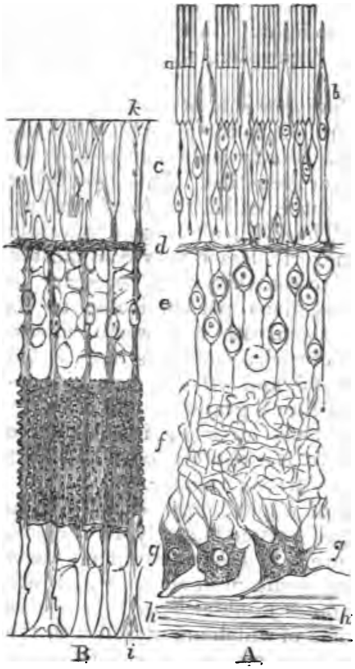

Fig. 66. Diagrammatic view of a section of the retina (magnified about 250 diameters): A, the nervous elements from which the connective tissue, B, has been separated; *a*, the rods; *b*, the cones; *c*, outer granular layer; *d*, intergranular layer; *e*, inner granular layer; *f*, molecular layer; *g*, ganglionic corpuscles; *h*, layer of nerve fibres; *i*, the inner, and *k*, the outer, limitary membrane. (*Schultze.*)

All these layers of the retina, except that of the rods and cones, are held together by connective tissue, which extends from *i*, where it forms the *inner* or *anterior limitary* membrane, to *k*, the *outer* or *posterior limitary* membrane.

At the blind spot there are no *rods and cones*, but at the yellow spot the cones are very numerous, while all the other layers become very much thinner.

Besides the *optic nerve*, which is alone concerned in the transmission of impressions of light, the various parts of the eye are supplied with branches from the third and fifth cranial nerves, and also from the sympathetic.

The artery which supplies the retina with blood enters the sclerotic, as has been mentioned, in the centre of the optic nerve (fig. 65, *p*); and its branches ramify in the retina between the internal limitary membrane (*i*) and the *inner* *granular layer* (*e*); so that they lie altogether in front of the layer of rods and cones, which, as we shall presently see, are alone sensitive to *light*. Numerous small arteries supplying other parts of the eye, enter at the back of the sclerotic.

Functions of the Parts of the Eye. All the various parts of the eye just described subserve one or other of two distinct offices. One part, namely, the *retina*, having for its function the conversion of luminous impressions into nervous influences, capable of giving rise in the brain to the sensation of light; while all the other structures form portions of an apparatus for throwing distinct images of external objects upon the retina.

Refraction of Light. When light passes obliquely from a rarer to a denser medium, as for example from air into glass, it is bent out of its straight course, or *refracted*. When a beam of light is made to pass through a *doubly convex lens*, the refraction takes place in such a manner, that after passing through the lens, the rays converge approximately to a point, or *focus* as it is termed. The effect of this may be easily seen on placing a lens between a candle flame and a screen; by moving the lens gradually from the screen, a point will be reached, when an inverted image of the flame will be seen upon the screen. If the lens be fixed in this position, and the flame gradually removed from it, it will be found that the image on the screen becomes less and less distinct. If now the lens be moved nearer to the screen, the image will regain its distinctness. The clear image might also be again obtained by substituting another lens of greater focal length.

Function of the Crystalline Lens. The crystalline lens acts in just the same way as the lens in the above experiment, throwing images of external objects upon the retina, which forms a screen. The luminous effect is increased by the retina being enclosed in a chamber from which all other light is excluded. The eye is in fact a camera of a very perfect kind. When rays of light reflected from an object strike upon the *cornea*, they become to some extent refracted; the *crystalline lens*, however, is the chief means by which they are brought to a focus upon the retina.

If the parts of the eye are arranged so as to throw upon the retina a distinct image of an object which is distant, say ten inches from the eye, it will be obvious from what has been said, that objects that are at a greater distance will not be clearly depicted on the retina. And as it is necessary for distinct vision that all objects should be clearly focussed, it follows that near and distant objects cannot be distinctly seen at one and the same time; this is a fact with which we are all well acquainted.

Adjustment of the Eye to near and distant Objects. The means by which the lens of the eye is adjusted in order to change its focus for near or distant objects is very peculiar. It can be shown by experiment that the front face of the *lens* becomes *flatter* when distant objects are looked at, and more convex when the eyes are fixed upon near objects. This change is generally acknowledged to be brought about in the following manner. We have seen how that the lens is attached to the ciliary processes of the choroid by the ciliary ligament; now under ordinary circumstances this ligament is in a state of tension, consequently the lens, which is very elastic, is flatter than it would be if the tension of the ligament were relaxed. The contraction of the ciliary muscle (fig. 65, *l*) draws the choroid coat more forward; this of course allows the tension of the ciliary ligament to relax, the result being that the lens, in virtue of its own elasticity, becomes more convex. If after looking at a distant object the eyes be directed suddenly to some near object, a feeling of effort will be experienced; this is caused most probably by the contraction of the ciliary muscles.

The Uses of the Iris. It is found that the rays of light passing through an ordinary glass lens near the circumference, are not brought to a focus at the same point as those which pass through nearer the middle; the consequence is, that the image appears more or less blurred. This is remedied by using an opaque plate or diaphragm, with a hole in the centre, to intercept the rays near the circumference of the lens. In the eye, the *iris* acts as a diaphragm; but with this peculiarity, that the size of the aperture can be altered to admit more or less light; and further, these alterations take place involuntarily, being entirely due to reflex action. If we look at a bright light, the effect upon the retina is such, that an afferent impulse is carried to the brain, and there reflected upon nerves connected with the muscular fibres arranged around the aperture of the iris (p. 130), causing them to contract, and consequently to reduce the size of the pupil. The extraordinary manner in which the pupil of a cat's eye contracts and dilates is a matter of frequent observation.

The Point of Distinct Vision. It is necessary to *distinct* vision that the image of an object be not only clearly formed upon the retina, but also that the image fall upon the *macula lutea.* If it fall upon any other part of the retina it may be visible, but not distinctly. When we wish to see an object clearly, we instinctively turn the eye into such a position that the image falls upon the *macula lutea.*

The Blind Spot. It has been stated above that this spot is altogether insensible to light; this may be shown in the following manner:—Make on paper two black dots about three inches apart; then close the left eye, and holding the paper at a distance of about twelve inches, look steadily at the *left* dot with the *right* eye. In this position both dots can be seen. Now bring the paper gradually nearer to the eye: at a certain point the right dot will disappear. Bring the paper nearer, and it will again come into view. It can be proved that the dot disappears when its image falls upon the point of entrance of the optic nerve. This point is therefore termed the blind spot.

The Functions of the Rods and Cones. The parts of the retina believed to be chiefly concerned in the *reception* of luminous rays are the *rods* and *cones;* and lying as they do nearest the choroid, the light in order to reach them has to pass through all the other layers of the retina. The inference that the impressions of light are received by the layer of rods and cones, and not by the fibres of the optic nerve, is founded on the following facts:—

1. At the *blind spot* there are no *rods and cones,* but many optic nerve fibres.

2. At the *macula lutea,* the place of most perfect vision, the layer of *rods and cones* is somewhat thicker, the *cones* in particular being very numerous; while the nerve-fibres and other layers of the retina are absent.

3. We have seen that the bloodvessels of the retina ramify between the *inner granular layer* and the *internal limitary membrane* (p. 132); and as the light has to pass through these layers before it reaches the *rods and cones,* the shadow of the bloodvessels must be thrown upon the *rods and cones,* and if these are sensitive to light we should expect to see the shadows of the vessels. Ordinarily they are not seen; but if, on entering a dark room, the eyes be directed towards one of the dark walls, and a light be moved up and down close to the outer side of one of the eyes, shadows of the bloodvessels will be seen as red branches, cast apparently upon the dark wall.

Optic Nerve not affected by Light. The *optic nerve* itself is insensible to light, but if it be irritated by pinching or galvanizing, nervous influences giving rise to the sensation of light are carried to the brain.

Duration of Impressions of Light. The effect of light continues upon the retina about an eighth of a second after the light has ceased to fall upon it; consequently, if less time than this intervene between two impressions of light, they will give rise to but one sensation. Hence it is that an object whirled rapidly round appears as a circle, and not as a single object in any one place.

Temporary Blindness. The sensibility of the retina to impressions of light is very soon impaired. If we look steadily at a bright spot on a black ground for a time, and then look at a sheet of white paper, a dark spot will be seen. This is caused by the part of the retina on which the bright spot falls becoming for a time partially blinded, consequently the light reflected from the white paper has not the same effect upon it as upon the surrounding parts.

The most curious effects of temporary blindness are observed in connection with colours. Ordinary white light is made up of rays of all the colours of the spectrum. Normally the retina is sensitive to each of these colours, and when they all fall upon it at the same time the sensation of white is produced.* If a bright *red* spot upon a white ground be looked at steadily for some time, and then the eyes be turned to a sheet of white paper, a *green* spot will be seen. The reason is that the part of the retina on which the red light falls, becomes to a certain degree temporarily blinded to that colour; hence, when light from the white paper strikes it, the red constituent produces no effect, and the combined action of the other rays gives rise to the sensation of green. If a green spot be first looked at, then upon turning to the white paper a red spot will be seen; red and green being what are known as complementary colours. These appearances are termed *ocular spectra.*

Colour Blindness. Inability to perceive certain colours, called *colour blindness*, is with some people a permanent infirmity. Instances are occasionally met with of persons quite incapable of perceiving any colour; but perhaps the most common and at the same time the most remarkable cases, are those of persons who cannot distinguish red from green; to whom red sealing-wax and green leaves appear of similar tint.

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* It is not necessary that all the colours should be present in order to produce white; *yellow and blue rays* when combined appear white, and so do *red and greenish blue*, and *greenish yellow and violet.* Any two colours which when combined produce white are termed *complementary*.

Inversion of Images. The image of an external object is always inverted upon the retina; notwithstanding this, the mind perceives the object in an upright position. Why this is it is not easy to explain, but it appears to be due to the fact that the mind, from its earliest development, has been led by the assistance of the sense of touch, to refer an impression received upon the lower parts of the retina to the upper part of an external object, and *vice versâ;* and similarly those received upon the right side of the retina to the left side of an object, and *vice versâ.*

The power we possess of determining the true direction of an object, although its image must be depicted upon the opposite side of the retina, is due to a similar education of the visual sense.

The Combined Action of the two Eyes. We have hitherto simply considered the action of a single eye, but there are certain points with regard to the combined action of the two eyes which must be noticed.

When both eyes are directed towards an object, an image of the object is formed upon each retina; consequently there must be two sets of impressions of the same object, although, as a rule, the mind perceives but one. It is necessary, however, in order that the *two* images may be perceived as *one*, that both eyes be so directed that the image in each falls upon the *yellow spot* (or upon what have been termed *corresponding portions* of the two eyes); ordinarily the requisite adjustment takes place involuntarily, but if it do not take place, the impression of two images is conveyed to the brain. This is easily proved. Let some object be looked at with both eyes—the brain will perceive but one object. Now press gently upon the side or upper part of one eye; by so doing the eye is pushed out of its proper position, and the image is caused to fall upon another part of the retina, the result being that impressions of two images are conveyed to the brain, and the mind cannot by any effort divest itself of the idea of two objects so long as the eye remains out of position. If now the finger be gradually removed, the two images appear to come nearer and nearer, until they blend into one.

Why it is that two images falling upon *corresponding parts* of the two retinæ are only seen as one, has not been satisfactorily explained. It has been considered by some persons to be due to the decussation of the optic nerves (p. 110); but it appears most probable that it is the result of an unconscious mental action, somewhat similar to that by which the inverted image upon the retina is referred to an upright position (p. 138).

When a solid body is looked at with both eyes, the images formed upon the two retinæ are not exactly alike, for the right eye will see somewhat more of the right side, and the left eye rather more of the left side; so that to some extent we look round the sides of a solid object; this enables us to see objects *in relief*, and to judge of their solidity.

If a correct drawing were made of a solid body as it is seen by the right eye, and another as it is seen by the left, and the images were to be made to fall upon *corresponding parts* of the two retinæ, an impression of the object *in relief* would be conveyed to the brain. This is what is done by means of the *stereoscope*.

Appendages of the Eye. Each eye is surrounded except in front by fat, which forms a soft cushion for it to rest upon, and enables it to be moved with the greatest ease.

The Eyelids. In front the eye is protected by the upper and lower eyelids, or *palpebræ*. Each lid consists of an external layer of skin supported by a thin plate of soft cartilage. Between the skin and the cartilage are bands of striped muscular fibre, arranged in a circular manner, and forming the *orbicularis* muscle, which by contracting closes the eyelids (fig. 16). The upper lid is raised by a special muscle, the *levator palpebræ*, which passes from the lid to the back of the orbit (fig. 69, *g*). There is no special muscle to depress the lower lid. Both lids are lined with a very delicate and exceedingly senbundle, but although they are brought into such close relation with the fibres they do not enter them.

When the fibres contract, the muscle is reduced in length, but its bulk is not lessened; what is lost in length being gained in thickness.

Muscular fibre is of two kinds, *striped* and *unstriped* (p. 167), which differ in their properties as well as appearance. When a striped muscle is irritated, whether directly or through a nerve, contraction takes place instantly, and relaxation the moment the irritation is removed. In the case of *unstriped* muscles the contraction produced by irritation is slower, and does not cease with the irritation.

All muscles retain, for some time after death, the power of contracting under irritation; but sooner or later this power goes, the muscles grow rigid, and the limbs become fixed in the position they may chance to have assumed when this stiffening, or *rigor mortis*, begins. The rigidity is produced by the coagulation of a fluid termed *myosin.*

Unstriped Muscles. The muscles of the walls of the alimentary canal, the bloodvessels, the lymphatics, the ducts of glands, the urinary bladder, and the iris, are unstriped, and on account of their mode of arrangement are termed *hollow muscles.* Unstriped muscular fibres are also found in other parts of the body.

Unstriped muscles are not under the control of the will, and are therefore termed *involuntary muscles.*

The muscles of the alimentary canal arranged in longitudinal and circular layers, give rise to the *peristaltic* movement by which the food is gradually passed along through the œsophagus, stomach, and intestine (p. 45).

The action of the muscular coats of the arteries in regulating the supply of blood has already been noticed (pp. 72, 88), so also has that of the muscular fibres of the iris (p. 135).

The muscles of the heart are of the *striped* kind; but, like the *unstriped* muscles, they are not under the control of the will. Their action, too, has already been considered (p. 68).

keep moist, but when the fluid is secreted in greater abundance, as in certain cases of mental emotion, the lachrymal ducts cannot carry it away quickly enough, and the excess flows down the cheeks as *tears*.

The Muscles of the Eyeball. The eyeballs are capable of considerable and varied motion in their sockets by means of muscles, of which there are six to each eye. Four of them are straight, and are therefore called *recti* muscles. These are attached to the back of the orbit around the foramen through which the optic nerve passes, and extend forwards from thence to be inserted into the front part of the sclerotic, one being on the upper part, one below, and one on each side (figs. 68, 69).. The *superior rectus* muscle turns the front of the eye upwards, the *inferior rectus* brings it downwards, the *internal rectus* moves it inwards, and the *external rectus* turns it outwards. Two adjoining muscles contracting at the same time turn the eye in an oblique direction.

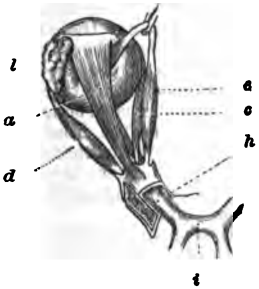

Fig. 68.

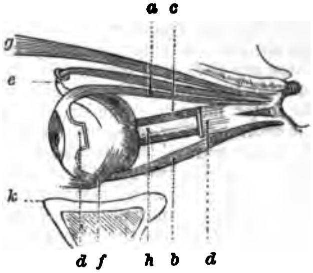

Fig. 69.

FIG. 68. Muscles of the left eyeball seen from above. (*Marshall.*)
FIG. 69. The same seen from the outer side (*Quain*): *a*, superior, *b*, inferior, *c*, internal, *d*, external, recti muscles; *e*, superior oblique, passing through its pulley, and *f*, inferior oblique muscle; *g*, muscle which raises the upper eyelid; *h*, optic nerve; *i*, decussation or chiasma of optic nerves; *k*, lower margin of orbit; *l*, lachrymal gland.

The other two muscles are the *superior* and *inferior oblique muscles* (*e*, *f*). The former arises with the four *recti* at the back of the orbit, and passes forward to the upper and inner corner of the margin of the orbit, where the skull upon the first cervical or *atlas* vertebra. In this instance the atlas vertebra forms the *fulcrum;* and when the face is turned upwards, the front part of the head is the *weight,* the force exerted by the contraction of the muscles at the back of the neck being the *power.* When the face is turned downwards the *power* is in front, and the *weight* behind.

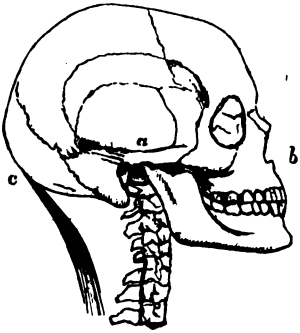

FIG. 71. The skull balanced upon the top of the vertebral column; an example of a lever of the first order: *a,* position fulcrum; *b,* weight; *c,* power. (*Marshall.*)

2. The movement of the pelvis upon the heads of the thigh bones in the act of raising the body from a stooping to an upright position. In this case the head of the femur forms the *fulcrum,* the body is the *weight,* while the *power* is exerted by the muscles at the back of the thigh which are attached to the ischium.

3. The *extension* (p. 153) of the fore-arm upon the upper-arm affords another example of the *first order.*

Examples of the Second Order. 1. The action of the foot when used as in walking on tiptoe. The ground upon which the toes rest is the *fulcrum,* the *weight* is that of the body upon the ankle joint, and the *power* the contraction of the muscles of the calf of the leg, which are attached by means of the *Achilles tendon* to the heel-bone, or *calcaneum.*

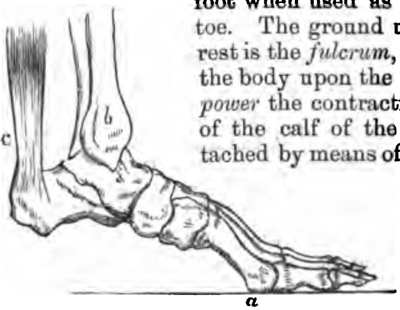

FIG. 72. The foot as used in walking on tiptoe; an example of a lever of the second order: *a,* fulcrum; *b,* weight; *c,* power. (*Marshall.*)

2. The depression of the lower jaw in opening the mouth. The *fulcrum* is the point of articulation of

the lower jaw with the skull, the *weight* is the tension of the muscles which close the jaw, the *power* is exerted by the muscles attached to the under part of the chin.

Examples of the Third Order. 1. The action of the elbow-joint in the bending or *flexion* (p. 153) of the fore-arm upon the upper arm. The *fulcrum* is the articulation of the humerus with the ulna and radius, the *weight* is that of the fore-arm and hand, the *power* is the effort of the *biceps* muscle, which is attached to the fore-arm just in front of the humerus.

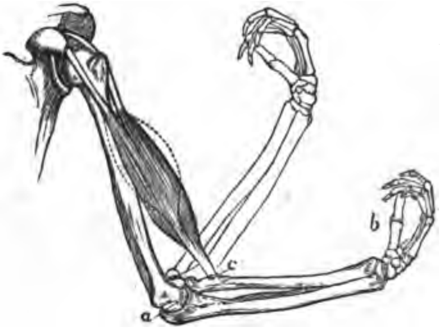

FIG. 72. Bones of the upper extremity, with the biceps muscle. The bending of the lower upon the upper arm, an example of a lever of the third order: *a*, fulcrum (the extremity of the humerus); *b*, weight (the hand); *c*, power (the contraction of the biceps muscle, which is here attached to the radius); the muscle is seen to be attached to the scapula by *two* tendons. (*Marshall.*)

2. The movement of the leg upon the thigh when it is bent or *flexed.* The *fulcrum* is the point of contact of the femur with the tibia, the *weight* is that of the leg, and the *power* the contraction of the muscles of the back of the thigh, which are attached to the leg near the fulcrum.

Joints. Bones which move upon one another possess *joints* or *articulations*, constructed so as to give the requisite amount of movement, without being liable to displacement.

Joints may be conveniently divided into two classes, the *imperfect* and the *perfect.*

Imperfect Joints. In these the bones are connected by ligament or cartilage interposed between and firmly attached to them, only such movements being possible as the elasticity of the connecting substance will allow.

The bodies of the vertebræ are connected with each other in this way; the bones being joined by elastic fibro-cartilage, which allows a considerable amount of motion in the vertebral column.

The attachment of the sacrum to the pelvic bones is another example of this kind of imperfect articulation.

Perfect Joints. In all perfect joints the articulating surface of each bone is covered by a smooth cartilage; and between the two surfaces thus formed there is a closed sac closely connected with the two cartilages. The sac is termed a *synovial capsule*, and secretes into its interior a viscid fluid called *synovia*, which serves to lubricate the joint. The surfaces by which bones articulate to form joints have very different forms, and consequently the amount and kind of motion which can take place varies greatly. The articulating surfaces are kept in their places by ligaments, which are differently arranged in different joints.

In some cases, as, for example, the *knee-joint*, plates of cartilage are interposed between the cartilaginous surfaces of the bones.

Illustrations of Perfect Joints. 1. The bones of the *carpus* and *tarsus* (pp. 11, 13) have mostly flattish articular surfaces, and being bound together by strong ligaments, are only capable of a limited, gliding kind of motion upon one another. These are therefore among the least mobile of perfect joints.

2. *Hinge Joints*, in which the articular surface of one of the bones has more or less the form of a cylinder, and fits into a corresponding hollow in the surface of the other bone. The elbow is the best example. The lower end of the *humerus* has the form of an irregular cylinder, the axis of which is at right angles to that of the humerus itself. This cylinder fits into a hollow formed by the ends of the *radius* and *ulna*. Movement can take place only in one plane, and the extent of the motion is limited by

the *olecranon* process of the *ulna* which forms the elbow, and prevents the arm from being bent backwards. The surfaces are kept in contact by ligaments which surround the joint, but chiefly by those upon the sides. In this, as in all perfect joints, there is a synovial capsule. The *knee* is another, though not so perfect an example, of a hinge joint.

3. When the articular surface of one bone is a ball which fits into a concave socket in the other bone, the joint is termed a *cup and ball joint.* The articulation of the head of the femur with the *acetabulum* of the pelvis, forms a joint of this character. In this case motion may take place in almost any direction, but is limited by the depth of the cup, by the ligaments which surround the joint, and by the *ligamentum teres*, which is a strong cord passing from a depression in the bottom of the cup to a pit in the head of the femur.

The articulation of the head of the *humerus* with the *glenoid cavity* of the *scapula* is another such joint; but the cup being much shallower than that of the hip, the humerus is allowed greater freedom of motion.

4. The articulation of the first and second cervical vertebræ, *atlas* and *axis*, as they are termed, forms what is known as a *pivot-joint.* The body of the *axis* is produced above into a peg or pivot, called the *odontoid process* (fig. 75, *d*). The *atlas* has no true body,

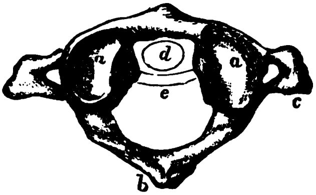

Fig. 74.

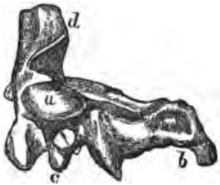

Fig. 75.

FIG. 74. Atlas vertebra viewed from above: *a*, *a*, the two concave surfaces which articulate with the two condyles of the skull; *b*, neural spine; *c*, transverse process; *d*, position of odontoid process of atlas; *e*, transverse ligament. (*Gray.*)

FIG. 75. Axis vertebra viewed from the left side: *a*, one of the convex surfaces articulating with atlas; *b*, neural spine; *c*, transverse process; *d*, odontoid process. (*Gray.*)

or *centrum*, but is in the form of an irregular ring (fig. 74). In its natural condition a strong ligament passes across this ring, and separates the aperture into two parts; the hindmost is the neural arch, and the foremost receives the *odontoid* process. Upon the upper face of the axis, on either side of the odontoid process, a somewhat rounded surface articulates with a corresponding surface upon the lower face of the atlas. By this arrangement the atlas is enabled to turn upon the *pivot* formed by the odontoid process, but the extent of this lateral motion is limited by certain ligaments.

Three ligaments are connected with the point of the odontoid process (fig. 76); two pass, one on each side, (*e*), to the margin of the *occipital foramen* of the skull and, on account of their preventing the skull from turning too far round upon the axis, are termed *check* ligaments; the third passes to the front margin of the *occipital foramen* (*f*). A *broad ligament* (*d*) also connected with the front margin of the same foramen passes over the three ligaments just mentioned and the odontoid process, and is attached to the bodies of some of the vertebræ which form the front wall of the upper part of the neural canal.

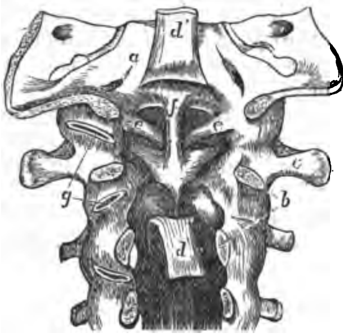

FIG. 76. The neural canal in the upper part of the neck, laid open by the removal of the neural arches of the vertebræ and the back portion of the skull: *a*, basal portion of skull; *b*, cut ends of neural arches of atlas and axis; *c*, transverse process of atlas; *d*, *d'*, the broad ligament, extending from the front margin of the foramen magnum, down the neural canal, upon the hinder surface of the bodies of the vertebræ, it has here been cut through and turned back; *e*, check ligaments attached to odontoid process and sides of foramen magnum; *f*, ligament attached to point of odontoid process and front of foramen magnum; *g*, synovial capsules between the articulating surfaces: they have been laid open upon this side. (*Gray.*)

Different Movements of the Limbs. When a limb is bent upon itself it is said to be *flexed*, and the muscles by which it is performed are termed *flexors*. The bending of the lower upon the upper arm, the bending of the leg upon the thigh, as in kneeling, and the closing of the fingers upon the palm of the hand, are instances of *flexion*. The straightening out of a limb is termed its *extension*, and the muscles by which this is accomplished are termed *extensors*.

When a limb is drawn towards the middle line of the body it is said to be *adducted;* when it is moved away from the middle line it is said to be *abducted*. A limb is *rotated* when it is turned upon its axis; it is obvious that rotation cannot be complete, for in order to turn the limb quite round, certain muscles, vessels, and nerves would have to be torn away. The movement by which a limb is rotated so as to describe a cone around an imaginary axis, as in swinging round the arm, is called *circumduction*.

Many of the actions of the body are the result of the simultaneous contraction of many muscles. The act of standing upright, from the ease with which it is performed, might be considered a very simple matter, but such is not the case. The body has to be balanced upon the ankle joint, and in order to keep the tibia and fibula steady upon the ankle joint, the contraction of the muscles of the calf and front of the leg must be so nicely balanced that the leg may not be bent too much forward or backward. The knee-joint must likewise be kept steady by the muscles of the front and back of the thigh. The pelvis has to be maintained in a proper position upon the heads of the femurs by appropriate muscles. The spinal column is kept erect by the muscles along its back and front, and the head is prevented from falling forward or backwards by the balanced contraction of muscles attached to it in front of and behind the spinal column.

THE ORGAN OF VOICE.

The Structure of the Larynx. The organ of *voice* is a peculiar motor apparatus, situated at the top of the trachea, and termed the *larynx*.

Above the uppermost ring of the trachea is a complete ring of cartilage which is deeper behind than in front and called the *cricoid* cartilage (fig. 77). Above and partly outside the *cricoid* is the *thyroid* cartilage, which is deeper than the cricoid, but open behind. When seen from above it has the form of the letter V (fig. 78) with the angle turned forward. The posterior edges of the thyroid are produced above and below into processes, or *cornua* (fig. 77); the lower of these upon each side is attached by ligaments to the outer surface of the *cricoid*. The upper cornua are connected with the hyoid bone. Two small somewhat pyramidal cartilages, the *arytenoids* (*c*), are movably attached to the upper and posterior part of the *cricoid*. From each arytenoid a band of elastic tissue (fig. 78, 5) passes forward, and is attached to the inner and front part of the *thyroid* cartilage towards its lower margin; these two bands are called the *vocal chords*.

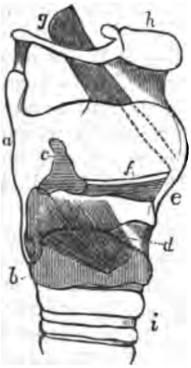

FIG. 77. Diagrammatic view of the larynx. The internal parts are represented as seen through the thyroid cartilage: *a*, thyroid, *b*, cricoid, and *c*, arytenoid, cartilages; *d*, crico-thyroid muscle; *e*, thyro-arytenoid muscle; *f*, vocal chords; *g*, epiglottis; *h*, hyoid; *i*, trachea.

Muscles of the Larynx. Upon each side, a triangular muscle, termed the *crico-thyroid* (fig. 77, *d*), passes upwards and backwards from the outer and front part of the cricoid cartilage, to the lower part of the thyroid cartilage. The two arytenoid cartilages are connected by the *posterior arytenoid muscle* (fig. 78, *d*), which passes from one to the other. Three other muscles are also attached to each arytenoid cartilage, viz., the *posterior crico-arytenoid muscle* (*c*), which, passing from its back part, is attached to the hinder portion of the cricoid cartilage; the *thyro-arytenoid* muscle (*a*) extending from the front of the arytenoid cartilage to the angle of the thyroid cartilage, and lying beside the vocal chord of the side to which it belongs; and the *lateral crico-arytenoid* muscle (*b*), attached to the side of the arytenoid cartilage, and passing downwards and forwards, to the cricoid cartilage.

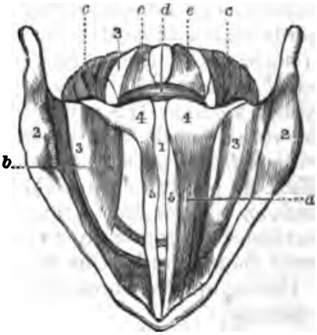

FIG. 78. The larynx dissected and viewed from above. Some of the muscles have been removed from each side for the sake of distinctness: 1, aperture of glottis; 2, upper border of thyroid cartilage; 3, cricoid cartilage; 4, arytenoid cartilage; 5, vocal chords; *a*, thyro-arytenoid muscle; *b*, lateral crico-arytenoid muscle; *c*, posterior crico-arytenoid muscle; *d*, posterior arytenoid muscle: *e*, posterior crico-arytenoid ligament.

The larynx is lined with mucous membrane, which extends over the parts just described so that the muscles and cartilages cannot be seen until this membrane is dissected off. A little above the *true vocal chords* the mucous membrane forms a fold upon each side, these are called the *false vocal chords*. Just below them, upon each side, there is a cavity, termed a *ventricle*.

Action of the Larynx. The true vocal chords are the important part of the apparatus, for it is their vibration which produces the voice. When they are tightly stretched and near together, they vibrate more rapidly, and emit a high tone; but when they are less tense and wider apart their vibrations are less rapid, and a relatively low tone is the result.

The tightening and relaxing of the vocal chords is accomplished by the muscles of the larynx. It will be seen by reference to figure 77 that when the *crico-thyroid muscles* (*d*) contract, the thyroid cartilage will be drawn down towards the cricoid cartilage; the consequence of this will be that the distance between the arytenoid cartilages and the front of the thryoid cartilage will be increased, and the vocal chords will be stretched. At the same time they are still further tightened by the contraction of the *posterior crico-arytenoid* muscles (fig. 78, *c*), which tend to draw the arytenoid cartilages backwards.

When the vocal chords are to be relaxed, the muscles just mentioned cease to contract, and the *thyro-arytenoids* (*a*) come into play, drawing the thyroid cartilage upwards and backwards; the arytenoid cartilages are also to some extent drawn forwards by the *lateral crico-arytenoid* muscles (*b*). The *posterior arytenoid* muscle (*d*) brings together the arytenoid cartilages, and so causes the vocal chords to approach each other. The *lateral crico-arytenoid* muscles (*b*) also tend to produce the same effect, by partly rotating the arytenoid cartilages. The *posterior crico-arytenoid* muscles (*c*) cause the arytenoid cartilages to rotate in an opposite direction, and the vocal chords are by this means drawn apart.

During ordinary breathing the vocal chords are widely separated.

The Voice. If the air be driven out of the lungs by an act of expiration, when the chords are in a state of tension, they vibrate and produce sound. This sound is called *the voice.*

The different musical sounds produced in singing depend upon the varying degree of tension of the vocal chords. The *compass* of the voice depends upon the extent to which the variations can take place. A practised singer can at will give the requisite tension for the production of any particular note.

The *quality* of a voice depends upon the structure of the larynx. In women and children the larynx is smaller and the vocal chords shorter than in men; consequently their voices have a higher pitch. The longer the chords and the larger the larynx, the deeper the voice.

Speech. Voice may exist without speech, as in many animals. Speech is the voice modified by the throat, tongue, and lips. In whispering the sounds are produced by the vibration of the lips.

PRACTICAL SECTION.

Muscular Contractility. The contractility of muscle when stimulated by the motor nerves with which it is supplied, may be conveniently studied in the frog. Take a frog which has just been killed by decapitation, and destroy the spinal cord by passing a wire down the neural canal, so as to prevent reflex actions. Lay the frog with its belly downwards upon a board, and with a scalpel make an incision in the skin along the back of the thigh. By carefully pulling the muscles apart a nerve will be seen which supplies the large muscle of the leg. If this nerve be galvanized, the muscle attached to the heel will contract, and extend the foot. It is better, however, to separate the muscle with nerve attached from the surrounding parts, being careful not to pinch or otherwise injure the nerve. Tie one end of the muscle to a support, and to the other end attach a weight just sufficient to keep the muscle straight. If now the nerve be galvanized, the muscle will contract and draw up the weight. This contraction takes place whenever the galvanic current is completed or interrupted, but does not continue while the current is uninterrupted.

For the microscopic examination of contracting muscular fibres, see page 168. For amœboid and ciliary movements, see pages 63 and 159.

Joints. The various joints mentioned in the previous part of this chapter may be examined in the rabbit. In the first place the muscles or sinews which obscure any joint should be cleared away, and the movements of which it is capable observed. Then the ligaments may be cut through, so as to separate the bones and allow the articulating surfaces to be examined.

The Larynx. Having removed the tongue, with the trachea attached to it, from the head of a rabbit (p. 85), the glottis and vocal chords may be first examined. It will be found convenient to cut off the greater part of the trachea and by means of pins to fix upon a board the parts about to be examined. The loose tissues should then be dissected off the exterior, so as to show the cricoid and thyroid cartilages, and the *crico-thyroid* muscles. To expose the muscles which lie in the interior, one side of the cricoid and thyroid cartilages must be cut away and the mucous membrane lining the interior dissected off.

CHAPTER XIV.

PRACTICAL HISTOLOGY.

Definition, etc. *Histology* is that branch of anatomy which treats of the minute structure of the tissues of the body. It has been found necessary in previous chapters to speak somewhat in detail of certain tissues of the body; but little has been said concerning their microscopic structure; with this the student should now make himself familiar.*

Cells. At a very early stage of development, all the tissues of the body are composed of small rounded particles of a proteinaceous substance called protoplasm. The exterior of these particles, or *cells* as they are termed, is very often more dense than the interior, and forms a kind of membranous sac around the more fluid portion. Within each cell is a small particle, or *nucleus*, which differs somewhat from the rest of the cell substance. Smaller particles still are occasionally to be seen within the nuclei; these are termed *nucleoli*. As life advances the cellular structure of many tissues is lost or obscured, but in others it is retained throughout life.

Epithelium. This is perhaps the simplest form of tissue in the adult body. It is composed of a number of nucleated cells, the deeper layers of which are constantly growing, while those upon the surface are as constantly being cast off or worn away.

Epithelium is found covering the walls of the alimentary canal and cavities of the body, and also the *free* surfaces of the organs of the body. It exists in several different forms.

1. *Squamous Epithelium.* In this kind of epithelium the cells become flattened so as to form scales as they approach the free surface.

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* See Appendix, page 174.

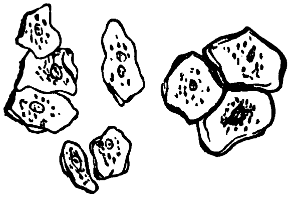


FIG. 79. Squamous epithelium from the mouth (magnified 175 diameters). (*Kölliker.*)

The mucous membrane of the mouth is an example, and its cells may be easily examined. With an ivory paper-knife scrape the back of the tongue or the inside of the lips; place the substance thus obtained upon a glass slip; cover it with a thin cover-glass (Appendix p. 174), and if necessary add a drop of water. Examine it with the microscope, and the irregularly formed epithelial cells will be easily seen. Allow a small drop of magenta staining fluid (p. 175) to run under the cover-glass, and in a short time the nuclei of the cells will become stained.

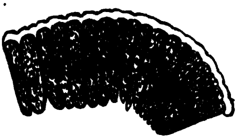
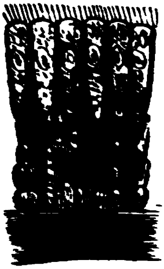


FIG. 80 Cylindrical epithelium from a villus of a rabbit's intestine (magnified 300 diameters). (*Kölliker.*)

2. *Cylindrical* or *Columnar Epithelium.* In the epithelium of some parts of the body, the surface cells are elongated and arranged side by side, as in fig. 80. An example of this kind may be found in the villi of the intestine. Open the small intestine of a rabbit, just killed, and with fine scissors snip off some of the villi and place them with a drop of salt solution (p. 176) upon a glass slip; cover with thin glass and examine with the microscope; add magenta stain, and re-examine.

3. *Ciliated Epithelium.* In the trachea and some other parts, the free surfaces of the epithelial cells are provided with minute hair-like processes which, during life, are constantly vibrating. An example of ciliary motion may be readily obtained. Open the mouth of a frog, and with the point of a knife scrape the roof so as to obtain a minute portion of the mucous membrane. Place this in salt solution, upon a slip of glass, cover, and examine it with the microscope. The cilia move very rapidly when quite fresh, and are therefore not easily

seen, but the currents which they cause are readily observable.



[illegible]

A portion of the gill of a muscle, observed in the same way, affords another example of ciliary motion.

4. *Globular or Spheroidal Epithelium.* In some glands, and certain other parts, the epithelial cells retain their globular form, becoming neither compressed nor elongated, and are hence termed globular or spheroidal.

Examples are found in the gastric glands (p. [illegible]).

Take out the stomach of a cat or dog recently killed, open it and wash with salt solution; cut out some pieces about half an inch square from the larger end, and put them in spirits of wine or chromic acid solution (p. [illegible]). When sufficiently hardened, take a piece, and having dried the surface, embed it in wax (p. [illegible]) with one edge upwards for the purpose of cutting thin sections perpendicular to the surface.

Hold the wax in the left hand, and with a sharp razor cut [illegible] sections, [illegible] wax and specimen. The razor should be kept wet with [illegible]. [illegible] When several sections [illegible] [illegible] [illegible]

The Epidermis. The epidermis is composed of cells precisely similar to those of squamous epithelium, but the outer layers become much more horny, and lose all traces of nuclei. The structure of the epidermis has already been considered (p. 92).

Nails. The nails are really modifications of epidermis. Under them the *dermis* is raised up into numerous parallel ridges, which are extremely vascular. Upon these the epidermic cells are constantly growing, and as they are pushed outwards by the new cells formed below, become flattened and firmly agglutinated. At the back (or *root*) of the nail the skin forms a fold, and within this fresh epidermic cells are constantly being added to the base of the nail, so that it is always being pushed forward, at the same time that it is increased in thickness by the addition of cells from below.

Hair. Hairs, like nails, are epidermic structures. The root of each hair is sunk in a deep depression of the integument, called a *hair sac* (fig. 82). At the bottom of the sac the dermis is raised into a minute papilla, from the surface of which epidermic cells are developed. These coalesce and become horny; and being thrust upwards by the new cells developed below, form the *shaft* of the

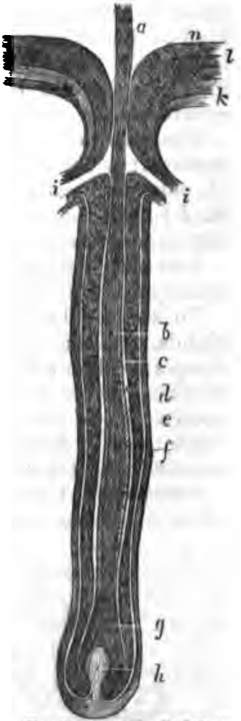


FIG. 82. A hair in its hair-sac (magnified about 50 diameters): *a*, shaft of hair above the skin; *b*, cortical substance (the medulla, which occupies the centre of this, is not shown in the figure); *c*, cuticle; *d*, cavity of hair-sac; *e*, epidermis of hair-sac (root sheath); *f*, dermis of hair-sac; the bulb, *g*, is the newest portion of the hair, growing upon the papilla, *h*; *i*, ducts of sebaceous glands; *k*, dermis; *l*, epidermis; its horny layer *n*, is seen passing a short distance into the hair-sac. (*Kölliker.*)

hair which appears above the surface of After a certain time a new hair sac is for kind of bud, from the side of the old one, a it appears a new papilla, upon which a grows. The old papilla and sac cease gro eventually die away.

The shaft of a hair of the head consist portions: a central pith or *medullary* matt of elongated cells, termed the *cortical* sub 82, *b*); and the *cuticle* (*c*), which consists of overlapping, horny scales.

Into each hair sac, the ducts of two *seba* usually open (*i*); these glands secrete an oi

To see the hairs in their sacs with t glands, obtain a small portion of skin from sheep's head, cut the hair off and put the of wine. When sufficiently hard, embed i upon a slice of turnip, and with a razor cu Place them in diluted acetic acid for a fe examine with the microscope.

Cartilage. Cartilage is a firm, ela white substance formed of cells, but diff siderably already c cells are frequentl bules of lie close more o from ea *cellular* which elastici depends. The growth of cartilage ta plication of its cells. The cells beco subsequently separate into two parts size, and intercellular substance them. Cartilage contains no vessels

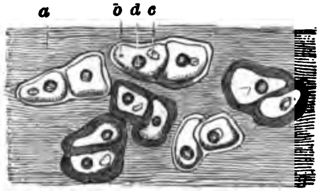


FIG. 82. A section from the cricoid cartilage (magnified about 230 diameters): *a*, matrix; *b*, cartilage cell; *c*, its nucleus; *d*, fat globule. (*Kölliker*).

Cartilage is very easily prepared f

the microscope, as it is sufficiently tough in its natural condition to be readily cut with a razor. Thin slices should be prepared from that upon the end of the femur, from one of the costal cartilages, and from the epiglottis; examine with the microscope and compare them.

Connective Tissue. This is more widely distributed than any other tissue of the body. It invests all the organs, and penetrates between the parts of which they are composed. It is the chief constituent of *tendons*, *ligaments*, the *sclerotic*, etc. It has a whitish appearance, and consists of wavy fibres which may by proper means be split up into extremely fine filaments or fibrillæ. Take a very small portion from one of the tendons of the foot of a rabbit or any small animal recently dead; place it upon a glass slip with a drop of salt solution; tear it to pieces with needles, cover it with thin glass, and examine with the microscope. The fine wavy filaments will easily be distinguished. Allow a drop of dilute acetic acid to run under the cover glass; the filaments will swell and become transparent. Occasionally fine fibres of elastic tissue may be seen which are not affected by the acid, and also nuclei which belong to small elongated cells called *connective tissue corpuscles*.

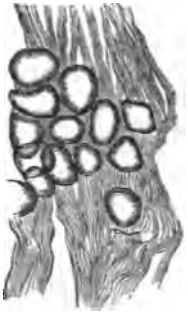


FIG. 84. Connective tissue with fat globules (magnified about 220 diameters). (*Kölliker.*)

Adipose Tissue. This name is given to those portions of connective tissue in which collections of *fat-cells* are found. The fat-cells have a most distinct cell wall, and are filled with an oily or fatty fluid. They are generally well surrounded by blood capillaries.

Elastic Tissue. Fibres of elastic tissue are very frequently found mixed with those of connective tissue, from which they differ in not swelling in acetic acid, and in having a tendency to curl up when broken across.

Take a very small portion of the *ligamentum nuchæ* of

an ox (this is the name given to the y
stance found at the back of the neck b

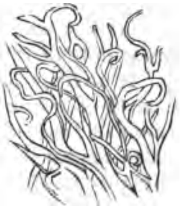


Fig. 85.

FIG. 85. Elastic fibres from the ligament between the
about 200 diameters). (*Marshall.*)
FIG. 86. Elastic tissue from an artery (magnified about

of the vertebræ), tease it out wit
of glass, in salt solution; cover
add dilute acetic acid, and comp
produced upon connective tissue.

Bone. If one of the long b
be cut longitudinally, it will be
soft and spongy (*cancellated*),

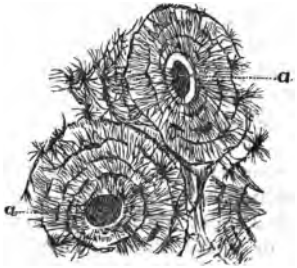


Fig. 87.

FIG. 87. Transverse section of bone (mag
three Haversian systems: *a*, Haversian can
these are the lacunæ, and the fine lines passing
FIG. 88. Longitudinal section of bone (
fig. 87. (*Kölliker.*)

and compact, and has a
fresh state contains the ma

sists of a basis of *animal matter*, in which *phosphate* and *carbonate* of *lime* are deposited, and it is these earthy matters which give to it its peculiar hardness. Take the femur of a rabbit, and with a fine saw cut it across. From one of the cut surfaces saw off as thin a slice as possible; rub both sides of this with the finger or a piece of cork upon a flattened piece of pumice stone, until it is considerably reduced in thickness, keeping it constantly wet with water. Then rub it in the same way upon a hone until sufficiently transparent for examination with the microscope. Wash it well with a camel's hair brush; put it on a glass slip with a drop of water, and cover it with thin glass. In such a section it will be seen that the bone is dotted with small spots or holes. These are the bloodvessels which supply the bone with nutriment, and are called *Haversian canals* (fig. 87, *a*). Round these the bony matter will be seen to be arranged more or less distinctly in layers, or lamellæ. Each Haversian canal, with the bony lamellæ surrounding it, is termed a *Haversian system.*

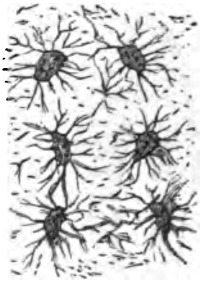


FIG. 89. Bone lacunæ and canaliculi (magnified about 250 diameters). (*Kölliker.*)

It will be further seen that there are numbers of very small, dark, irregularly shaped dots, arranged in circles around the Haversian canals. These are known as *lacunæ;* and the extremely minute lines which pass off from the lacunæ are termed *canaliculi;* they are really fine tubes connecting the lacunæ with each other.

In dried bones, the lacunæ are minute cavities which being filled with air, so reflect the light as to make them appear black when examined with the microscope.

A section should now be made of the same bone, in a longitudinal direction. The Haversian canals will be seen running more or less in the direction of the length of the bone, and giving off branches which communicate with neighbouring canals. The lacunæ and canaliculi will be seen scattered through the substance of the bone between the Haversian canals (fig. 88).

All bones are ensheathed in a tough layer of connective tissue, termed the *periosteum.*

There is a time in the life of an animal when the body is without bone, the positions and forms of the future bones being indicated either by *cartilage* or *connective tissue;* and it is by the deposition of calcareous salts within these tissues that the bone is formed. This *ossification* does not take place throughout the tissue at the same time, but commences at one or more points, from which it extends to the rest of the tissue. For example, the femur, and the humerus have each three chief points, one for the shaft and one for each end, and these do not unite until the animal is approaching maturity.

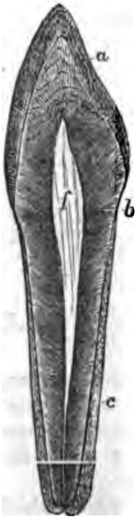


Fig. 90. Incisor tooth, longitudinal section: *a*, the enamel extending over the crown; *b*, dentine showing the tubules; *c*, the cement; *f*, pulp cavity.

Teeth.—The teeth, like the bones, consist of animal matters impregnated with *phosphate* and *carbonate* of *lime* (p. 38).

They are composed of three different substances, viz.:—

1. *Enamel*, which covers the crown of the tooth (figs. 90, 92), and is the hardest substance found in the body. It does not contain more than two per cent. of animal matter.

2. *Dentine*, which forms the chief part of the tooth.

3. *Cement*, which is a deposit of true bony matter around the fangs.

To see the arrangement of these substances and their microscopic characters, a section of a tooth should be made. One of the incisors of a sheep will answer very well, and sections may be prepared in the same way as those of what difficult to cut with a saw, but it can be reduced in thickness by means of a grindstone, or by rubbing upon a flat stone with emery powder.

When a longitudinal section of a tooth is examined with the microscope, the greater part of it is seen to be composed of a material in which a great number of very fine wavy lines may be traced, running from the cavity existing in the middle of the tooth, towards the exterior. This material is the *dentine*, and the fine lines are termed *dentinal tubules*.

The *enamel* forms a layer over the upper part of the tooth, and gradually thins away as it approaches the neck. It consists of a great number of fine six-sided fibres of extremely hard substance, set side by side perpendicularly to the surface of the dentine.

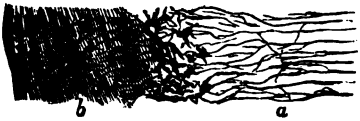


FIG. 91. A section of portion of tooth at the junction of dentine and cement (magnified about 175 diameters); *a*, dentinal tubules ending in irregular spaces; *b*, cement, showing one lacuna with its canaliculi. (*Kölliker.*)

The *cement*, which serves to keep the tooth firm in its socket, may be seen as a thin layer of bone upon the fang, and in it true lacunæ with their canaliculi are visible.

The cavity of the tooth is in the fresh condition occupied by a tissue richly supplied with bloodvessels and nerves, which is termed the *dental pulp*. The vessels and nerves enter the *pulp cavity* by an aperture at the end of the fang.

Striped Muscle. Striped muscular fibres are so called on account of the peculiar transverse striations which they exhibit when viewed with the microscope.

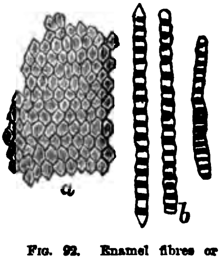


FIG. 92. Enamel fibres or prisms (magnified 350 diameters): *a*, view of the surface, showing the ends of the fibres; *b*, fibres isolated by treatment with hydrochloric acid. (*Kölliker.*)

In addition to the sheath of connective tissue by which the fibres of a muscle are all bound together, each fibre

has a special sheath of structureless membrane,
sarcolemma (fig. 94). The muscular fibres c
are of the striated kind, but have no sarcole

Besides the *transverse* markings, the fib
seen with the microscope to have a more
tinct *longitudinal* striation, and by careful
some of the fibres may be made to split
much finer filaments, or *fibrillæ* (fig. 93).

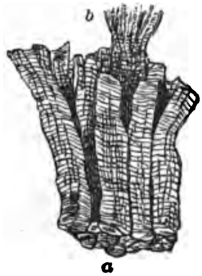


FIG. 93. A bundle of transversely striated muscular fibres (magnified about 150 diameters): *a*, end view of cut surface; *b*, a single fibre breaking up into its fibrillæ. (*Quain.*)

Muscular fibres, when treated with dilut
acid, have a tendency to break across ir
of the transverse ma
this way to form disc

The muscular fil
transverse striation
seen. Take a ver
of muscle which h
piece of beef or n
out with needles i
upon a glass slip
glass, and examin
scope. Careful
cover glass will s
fibres to break up

To see the sar
fresh frog's mus
in salt solution
may be pulled apart with forceps
fibres across: examine as before.
colemma may be seen in some cas
brane projecting beyond the fibre.

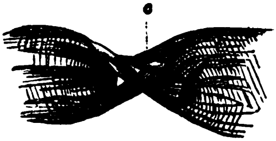


FIG. 94. A muscular fibre ruptured, to show the sarcolemma *c* (magnified about 300 diameters). (*Quain.*)

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Unstriped Muscles. *Unstriped* or *smooth* muscles are composed of elongated, more or less spindle-shaped, cells or fibres (fig. 96); each cell having an elongated rod-like *nucleus* (*a*). The fibres are bound together into bundles by connective tissue, but have no sarcolemma.

The smooth muscular fibres are somewhat more troublesome to demonstrate than the striated. The easiest process is perhaps to take a portion of the bladder of a frog, lay it in a solution (one or two per cent.) of acetic acid for a few minutes; wash the surfaces carefully with a camel's hair brush, place in water, and examine with microscope. The muscles will be seen forming a kind of network, and the fibres or cells will also be distinguishable.

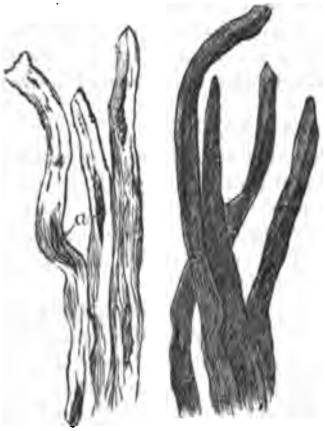

Fig. 95.

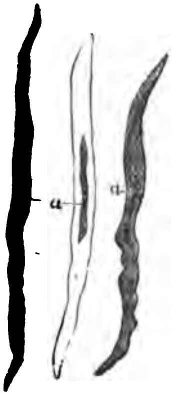

Fig. 96.

Fig. 95. Unstriped muscular fibres from the bladder (magnified 250 diameters). (*Quain.*)
Fig. 96. Unstriped fibres from an artery (magnified 350 diameters): the lighter ones have been treated with acetic acid to show the nuclei *a*. (*Quain*).

Glands. *The Liver.* The structure of this gland has already been described (p. 46). The distribution of the capillaries can only be seen in sections of specimens which have been carefully injected with some coloured fluid. The cells of the lobules may be seen by making thin sections of a rabbit's liver. Small pieces are placed for a few days (about four) in a solution of bichromate of potash (bichromate of potash, 1 part; water, 100 parts), then in spirits of wine for two days. Embed in wax, and cut sections (p. 176); stain with carmine solution (No. 2, p. 175), and examine in glycerin.

The Kidney. In order to see the Malpighian tufts and other bloodvessels, the kidney must be injected; much, however, of the structure of this organ may be made out by other means. Take a fresh kidney, and cut some transverse slices as thin as possible with a razor; lay them in a solution of bichromate of potash (see above) for a week; then tease out a portion with needles; wash in water; stain with carmine (24 hours), and examine in glycerin.

Gastric Glands. See pages 42 and 160.

Meibomian Glands. These may be observed by making transverse sections of the eyelid of a sheep. Prepare in the same manner as sections of skin (page 162).

Nervous Tissue. There are, as we have already seen (p. 98), two kinds of nervous tissue, the *nerve-fibres* and the *ganglionic corpuscles*.

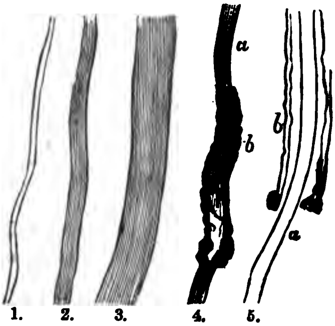

FIG. 97. Nerve fibres (magnified 350 diameters): 1, 2, 3, fibres of different sizes, in their natural condition; 4, 5, fibres showing the axis cylinder, *a*, projecting beyond, *b*, the sheath and its coagulated contents. (*Kölliker.*)

Nerve-fibres, when examined in a perfectly fresh condition appear as transparent, subcylindrical, oily-looking filaments. Very soon after death, ordinary nerves undergo a peculiar change, which enables us to see that each nerve-fibre consists of a central portion, termed the *axis-cylinder* (fig. 97, *a*), contained in a delicate membranous sheath. A space, however, exists between the sheath and axis, filled with an oily fluid, known as the *medulla.* Shortly after death, solid matter is deposited from this fluid upon the sides of the tube, and it is this change which enables us to distinguish the different parts of the fibre.

The *axis-cylinder* is, at least in some instances, composed of extremely delicate filaments, which have been called *primitive fibrils.*

Most of the nerve-fibres of the sympathetic system, the olfactory nerves, and the finer terminal portions of many cerebro-spinal nerves appear to have no medulla; such nerve-fibres are therefore known as *non-medullated nerve-fibres,* while those having the structure described above are termed *medullated nerve-fibres.*

In the larger nerves the fibres are bound together and surrounded by a sheath of connective tissue, called the *neurilemma.*

The *medulla* and *axis cylinder* may be seen by teasing out with needles a portion of a large nerve of a frog, in salt solution, and examining with the microscope.

Ganglionic Corpuscles. These are more or less spheroidal or stellate bodies, composed of translucent finely granular matter (fig. 98). Within this substance is a clear round space, the *nucleus,* which contains a much smaller spot, the *nucleolus.* One or more processes are given off from each corpuscle, which, in some instances, are connected with nerve-fibres, and in others join similar processes from other ganglia. Ganglionic corpuscles are found in the brain, the spinal cord, the ganglia of the posterior roots of the spinal nerves, the sympathetic ganglia, and also in some of the sensory organs. Preparations of them may be made by taking one

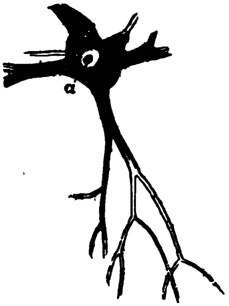

FIG. 98. A ganglionic corpuscle (magnified 175 diameters) from the grey matter of the spinal cord, showing at *a,* the nucleus and nucleolus. (*Kölliker.*)

of the ganglia from the posterior root of a spinal nerve of a recently killed frog, and teasing it out carefully with needles in salt solution. Examine with microscope, and afterwards add magenta or carmine solution, and examine again. A portion of the grey matter of the spinal cord of an ox or calf which has been hardened in bichromate of potash may be treated in the same way.

Preparation of Sections of the Spinal Cord. For this purpose the tissue must be perfectly fresh. Having carefully removed a portion of the spinal cord (say from the cervical region of a cat just killed), cut it in pieces about half-an-inch long and place them in spirits of wine for twenty-four hours, and then in the solution for hardening nerve tissue (p. 175. No. 4), diluted with an equal quantity of water. After a week or ten days, place them in some fresh solution of full strength, and allow them to remain about six weeks. Try if sufficiently hardened, by cutting a piece across with a razor, (it should have the consistency of a piece of cheese quite to its centre). If this is the case, embed the piece in wax, and cut very thin transverse sections, keeping the razor wet with spirit.

The sections may be floated off the razor into a glass of water, and then with a camel's-hair brush be removed to a watchglass full of water. Pour off the water, and add strong carmine solution (No. 3); cover with a wineglass and allow it to stand for twelve to twenty-four hours. Better results are sometimes obtained by using the carmine solution (No. 2), and allowing the sections to lie in it for a longer time. Pour away the carmine, wash quickly with water; or, if this is found to remove too much colour, with spirit and water. Cover the sections with spirits of wine, and leave them for a few hours. The thinner the sections, the less time will it be necessary for them to remain in the spirit. One of the sections should now be placed upon a glass slip, the spirit drained away, and a drop or two of *absolute alcohol* put upon it. After two or three minutes drain away the alcohol, watch until the spirit has evaporated and the section is nearly dry (it must not be quite dry, but sodden); then place a drop of turpentine by the side of the section and allow it to run underneath it. This drives off the remainder of the alcohol, and makes the section transparent. A drop of *Canada balsam* (p. 176) should now be allowed to fall upon the object, and a thin cover glass, well cleaned, placed over and gently pressed down, the excess of balsam being squeezed out at the edges. Use as little balsam as possible, and be careful to exclude air bubbles.

In such a section it is possible to see the distinction between the white and the grey portions (p. 99), the central canal, the anterior and posterior fissures, the anterior and posterior cornua of the grey matter, the exit of the spinal nerve fibres, the ganglionic corpuscles of the grey matter with their nuclei; and the longitudinal fibres, which, having been cut across, appear as small red dots surrounded by a clear space. Figure 47 was drawn from a section prepared as here directed.

Preparation of Sections of the Retina. The eye of a pig, sheep, or frog will answer for this purpose. The *rods and cones* being much larger in the frog are more easily made out. The eye, which must be taken from the animal directly it is killed, should have the sclerotic pierced with holes (p. 143) and be placed in Müller's fluid (No. 5, p. 176) for three weeks. Cut the eye in half transversely, and with care remove the retina. If the choroid adheres, do not attempt to separate it from the retina. Place in dilute spirit for three or four days. Embed in wax (p. 176) so as to cut sections perpendicular to the surface (p. 131). The razor must be kept well wetted with spirit or water, and great care will be necessary in removing the section from the razor to a glass slip. The sections should be floated off the razor. It is sometimes possible when small portions adhere to the wax, to lift them both together on to the glass slip.

When the section, which should be extremely thin, has been placed upon the glass, put a drop of carmine fluid (No. 2, p. 175) upon it, and cover with a watch-glass for from fifteen to thirty minutes; then add water, and allow the water to run off. Repeat this until the carmine is cleared away, taking care that the section itself does not float off. Add a few drops of spirits of wine for five or ten minutes; then treat with absolute alcohol, and proceed as directed for spinal cord sections (p. 172).

APPENDIX.

Instruments required for Dissections. A knife, scissors, forceps, and cutting nippers will be required to perform the dissections which have been proposed. The *knife* should be one of those usually made for this purpose, and of a medium size; the form is not of much consequence so long as it cuts well. The *scissors* should have both blades pointed. The *forceps* should be of steel, and have the points roughened so as to hold firmly. The *cutting nippers* should be pointed, and have the jaws set obliquely, as they are more convenient to use. All these instruments are to be obtained at any surgical instrument makers, and at most good tool shops.

Instruments, etc., required for Histological Work. 1. *Microscope.* A microscope is the most important instrument required for histological work, but it is at the same time the most expensive. Even a brief description of a microscope, and the method of using it, would require more space than the limits of this work will allow; but it may be well just to say that in order to be serviceable, the instrument should have a *good firm stand;* the motions for focussing should be *smooth and steady;* and above all *the lenses should be good.* For our present purpose, it should have at least two good object glasses, one magnifying about 50 diameters, and another giving an enlargement of from 250 to 300 diameters.

2. *Glass slips, cover-glasses, and watch-glasses.* All these may be obtained at any of the microscope manufacturers. The glass slips are usually made three inches long and an inch wide, and it is found convenient to use this one size. The thin glass used for covering objects is commonly about $\frac{1}{100}$ of an inch thick, and may be obtained cut in squares or circles of various sizes. A few

watch-glasses will be found very convenient for placing specimens in while staining, and for many other purposes.

3. *Razor.* For cutting sections of tissues, a razor is admirably adapted. Those sold as the *shilling army razor*, answer the purpose well. It must be remembered that in order to cut thin sections, the razor must be extremely sharp, and should therefore be carefully used, and occasionally sharpened on a *strop*.

4. *Needles.* These may be purchased mounted in handles, but ordinary sewing needles stuck in strips of firewood about the thickness of penholders, answer the purpose quite as well. To fix the needle in the wood, hold the needle with plyers, and force the point into the end of the strip of wood; withdraw the point, and reversing the needle, push the opposite end into the hole which has been made. Needles mounted in this way are required for pulling to pieces (teasing out) various tissues.

Staining Solutions. Some parts of tissues, such as nuclei, etc., are much more deeply stained by these fluids than others, and are thus rendered more distinct.

1. *Magenta Solution.* One grain of crystallized magenta dissolved in 50 grains of absolute alcohol, add about an ounce of distilled water. This is a powerful stain, and tints some tissues rapidly.

2. *Carmine Solution* (Beale's). Dissolve five grains of carmine in fifteen grains of strong ammonia, add one ounce of distilled water, filter through blotting paper, and add one ounce of glycerin and a quarter ounce of spirits of wine. Allow this to stand uncovered until the smell of ammonia has almost disappeared.

This solution is much used for staining tissues.

3. *Carmine Solution for nerve tissues.* Dissolve five grains of carmine in 250 grains of strongest ammonia, add 50 grains of glycerin.

This solution is used for staining sections of spinal cord or brain.

Fluids for Hardening Tissues. 1. *Spirits of Wine.* For all ordinary purposes the methylated spirit is used, it being very much cheaper than pure spirits of wine, and serving just as well to harden tissues.

2. *Absolute Alcohol.* This is rarely used for hardening tissues, but is of great service in freeing sections of tissues from water when they are to be mounted in Canada balsam (p. 172).

3. *Chromic Acid Solution.* Chromic acid solution is now frequently used in preference to spirits of wine for hardening some tissues. One part by weight of crystals of chromic acid dissolved in 400 parts of water is strong enough for all ordinary purposes. This solution does not penetrate so quickly as spirit. A large quantity of the fluid should be used.

4. *Solution for hardening nerve tissues.* Chromic acid, one part; bichromate of potash, two parts; water, 600 parts. This

is used for brain and spinal cord; it should be first used diluted with an equal quantity of water (p. 172).

5. *Müller's Fluid.* 2½ parts of bichromate of potash, and one part of sulphate of soda, dissolved in 100 parts of water. This is used for hardening the parts of the eye (pp. 143 and 173).

Salt Solution. When it is desired to examine certain tissues in their fresh condition it is necessary to do so in some fluid which does not alter them. The most convenient fluid for this purpose is made by dissolving one part by weight of common table salt in 130 parts of distilled water.

Method of Embedding Tissue in Wax. When it is required to cut sections of any tissue which cannot be held conveniently in the hand, it is often advantageous to embed them in wax. Five parts of *paraffin wax* mixed with about one to two parts of *lard*, or white bees-wax and olive oil, mixed in equal quantities, are used for this purpose.

To embed the tissue: make a mould by bending up a piece of stiff paper; a pill box will answer the purpose. Dry the tissue by placing it in spirit for a short time, and allow it to stand until the spirit has evaporated from the surface. Place it in the mould and pour round it the wax (which should not be hotter than is necessary just to make it fluid). When the wax is cold it may be taken out of the mould and the sections cut (pp. 160, 172, etc.).

Canada Balsam for mounting Sections, etc. Canada balsam as purchased at the chemist's does not do well for mounting *histological* preparations. It should first be allowed to stand in a warm place until quite hard and brittle, and then be redissolved with *benzole*. It should be made sufficiently fluid to drop readily from a glass rod.

Fluid balsam similar to this, or dammar fluid, which is used for the same purpose, may be obtained from the microscope makers.

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QUESTIONS FOR EXAMINATION.

The Numbers in parentheses show the pages on which the Answers will be found.

CHAPTER I.

1. Of what parts may the human body be seen to consist? (3)

2. What is the outer covering of the body called? (3)

3. What parts are seen when the skin is removed? (3)

4. What are muscles? (3)

5. What is the skeleton? (5)

6. What are the chief divisions of the vertebral column, and how many vertebræ are there in each? (5)

7. Describe the parts of a thoracic vertebra? (6)

8. Describe the positions and forms of the os innominatum and scapula. (7)

9. Describe the positions of the bones composing the cranium. (8)

10. Describe the positions of the bones forming the face. (9)

11. Describe the positions of the ribs, sternum, and hyoid. (6 and 10)

12. With what other bones is the ulna connected, and where are the metacarpals and clavicles to be found? (8 and 10)

13. Name the bones of the leg and foot. (12)

14. How are the thoracic and abdominal cavities separated? (16)

15. Name the chief organs in the thorax, and describe their relative positions. (13)

16. In what part of the body is the liver situated, and what other organs are lodged in the same cavity? (16)

17. What are the peritoneum and mesentery? (18)

18. Where are the brain and spinal cord situated, and by what membranes are they protected? (19)

19. What are nerves? (20)

20. What is that which separates the neural canal from the thoracic cavity? (7 and 19)

21. What would have to be removed in order to lay bare the upper part of the brain? (20 and 22)

CHAPTER II.

1. What is the difference between the study of anatomy and of physiology? (23)

2. What is meant by an organ of the body? Name several organs. (1)

3. Compare the production of force in the human body and in a steam engine. (23)

4. What is meant by the waste of the body, and how can it be proved to take place? (24 and 25)

5. What materials are given off from the body as waste? (24)

6. Name the organs by which the waste matters are separated from the body and the materials got rid of by each. (24)

7. Explain how it is that, while a healthy man is continually losing material by waste, he does not seem to alter in size or weight. (25)

8. What is digestion? and what organs are mainly concerned in its performance? (25)

9. Explain what part the blood plays in the nourishment of the body. (26)

10. What are the chief functions of the nervous system? (26)

11. Distinguish between local death and general death. (27)

12. How may the functions of the human body be classified? (27, 28)

CHAPTER III.

1. Of what chemical elements are proximate principles composed? (28)

2. What are the chief differences between the two great groups of proximate principles? (29)

3. From whence are the following substances obtained, and of what chemical elements are they each composed?—albumen, globulin, fibrin, casein, and gelatin (29, 30)

4. What are pepsin and ptyalin? (30)

5. Name some amyloid substances, and state in what respect they differ from fats and proteids. (31)

6. What are the general results of the decomposition of the body? (31)

7. Name some of the mineral substances found in the human body, and state where they occur. (31)

8. Of what chemical elements is the body composed? (32)

CHAPTER IV.

1. What is the chief difference between ordinary plants and animals as regards their food? (33)

2. Explain how plants supply animals with food, and how animals supply plants with the same. (33)

3. Show how food-stuffs may be conveniently classified, and in what respect this classification is not strictly correct. (33)

4. Give examples of each kind of food-stuff. Why are fats better heat-producers than amyloids? (34)

5. Why is a mixed diet necessary? (35)

6. Explain how it is that when the different kinds of food are properly mixed a much less quantity is required to sustain the body. (36)

7. Name some of the circumstances under which a variation in the kind and amount of food is requisite. (36)

CHAPTER V.

1. Describe the mouth, and name its various parts. (37)

2. Name the parts of a tooth. How many kinds of teeth has an adult, and how are they placed? (38)

3. How do the teeth of a child differ from those of an adult? (39)

4. Name the salivary glands, and state where they are situated. (39)

5. Describe the changes which a piece of bread undergoes in the mouth, and how it passes from the mouth into the stomach. (40)

6. Describe the general and minute structure of the stomach. (41)

7. Where is gastric juice secreted, and what are its uses? (43)

8. What are peptone and chyme? (44)

9. What glands pour their secretions into the small intestine, and where does this take place? (44)

10. Describe the general structure of the walls of the small intestine and the minute structure of one of the villi. (44, 46)

11. What are valvulæ conniventes, and what is their function? (44)

12. Describe the position of the cæcum and the structure of the colon. (46)

13. Describe the external form of the liver, and mention the more important organs with which it is connected. (47)

14. How is the liver supplied with blood? Trace the course of the vessels through the liver. (47)

15. What are the functions of the liver, and what are the constituents of its secretion? (48)

16. What are the uses of bile? (50

17. What evidence have we that the liver has other functions than the secretion of bile? (50)

18. Describe the position and structure of the pancreas. What is the nature of its secretion? (50)

19. Explain the peristaltic movement of the intestine. (45)

20. Where and how do the nutritious portions of food pass out of the alimentary canal? (44, 45, 52)

21. What is the cause of hunger and thirst? (53)

22. Describe the changes which each of the constituents of a beef-steak and bread is subject to—1st, in the mouth; 2nd, in the stomach; 3rd, in the small intestine; 4th, in the large intestine.

CHAPTER VI.

1. What is blood? (55)

2. Enumerate some of the chief uses of the blood. (55)

3. What is the difference between arterial and venous blood? (56)

4. Describe the appearances of a drop of blood when seen under a powerful microscope. (56)

5. Describe the process of coagulation, stating by what conditions it is hastened or retarded. (56)

6. What is blood plasma? (58)

7. Describe the structure of a red blood corpuscle. (58)

8. Describe the structure of a colourless corpuscle, and compare it with the red corpuscle. (59)

9. What gases are found in the blood? (60)

10. What changes does the blood undergo in the body, and where do they occur? (61)

CHAPTER VII.

1. What is meant by the circulation of the blood? (64)

2. Name the more important organs of circulation (65, &c.)

3. Describe the form, position, and structure of the heart. (65)

4. Describe the course which blood takes in passing from the right auricle to the left auricle. (65)

5. Through what vessels does the blood travel after leaving the left auricle before it reaches the right auricle? (64)

6. What causes the blood to circulate, and what determines the direction in which it moves? (69)

7. How is the heart itself nourished? Where is the pericardium? (66)

8. What is the difference between the structure of the wall of an artery and that of a vein? (70)

9. What are capillaries? Where are they found, and what is their use? (70)

10. Where are the mitral, the semilunar, and eustachian valves situated? (67, 68)

11. What is meant by the portal circulation? (65)

12. When the ear is placed against a person's chest, in the region of the heart, what sounds are heard, and how are they produced? (69)

13. What is the pulse? (71)

14. From what sources does the heart receive nerves? (68)

15. Explain the cause of blushing and pallor, pointing out especially the action of the nerves. (71)

16. How can the circulation of the blood be proved? (72)

17. Where is the thoracic duct situated, and what is its use? (74)

18. What are lacteals? From what source do they obtain the fluid they contain, and what becomes of that fluid? (75 and 53)

19. What is lymph, and how does it differ from chyle? (75)

20. Where are lymphatic vessels and capillaries to be found? (73)

21. Describe the structure of a lymphatic vessel and of a lymphatic gland. (74)

22. Where are the mesenteric glands situated, and what is their function? (75)

23. How does lymph differ from blood? (75)

24. Explain fully how the parts of a mutton chop, which has been eaten, find their way into the blood system, and how the tissues receive nourishment from them.

CHAPTER VIII.

1. What causes the heaving of the chest when we breathe? (80)

2. What is meant by diaphragmatic respiration, and what by costal respiration? (80, 81)

3. Describe the structure of the lungs and of the organs connected with them. (77)

4. Where are the pluræ situated? (79)

5. Why do the lungs during life always fill up the chest, and why when an opening is made into the thoracic cavity do they shrink? (79)

6. How is ordinary expiration performed? Explain the expiratory process fully. (81)

7. How are the lungs supplied with blood? (78 and 65)

8. Explain the changes that take place in the blood during its passage through the lungs. (61 and 84)

9. How much air is taken into the lungs at each inspiration, and what is the average total capacity of the lungs? (82)

10. Explain the phenomena of coughing and sneezing, and show in what particulars they differ. (82)

11. What is understood by complemental air, tidal air, supplemental air, and residual air? (82)

12. In what particulars does the air which passes out of the lungs differ from that which is taken in? Explain the cause of this difference. (83)

13. What is meant by the *diffusion of gases?* In what respect is this physical process insufficient to account for the exchange of gases in the lungs? (84)

14. Explain the effect upon the system generally when a person is confined for any length of time in a close and ill-ventilated room. (85)

15. Explain the successive effects produced in the system and circulation by a total deprivation of air, as in the case of drowning. (85)

16. At what rate does an ordinary man respire? How much air would pass in and out of his lungs during 24 hours? (82)

17. Describe the composition of ordinary air. (83)

CHAPTER IX.

1. What is the ordinary temperature of the human body? How and where is its heat evolved? (87)

2. What food-stuffs are best adapted for heating the body, and why? (88)

3. How are the internal and external parts kept at about the same temperature? (88)

4. Explain fully the manner in which the temperature of the body is regulated when it is exposed to extremes of heat or cold. (88)

CHAPTER X.

1. Explain the meaning of secre-

tion and excretion, giving examples of each. (89)

2. State what you know of the process of secretion. (89)

3. What are serous, synovial, and mucous membranes? Give examples. (90)

4. Where are the following glands situated?—sweat glands, Meibomian follicles, sebaceous glands, parotid glands? (91 and 39)

5. What are ductless glands? Give an account of the minute structure of one of them. (91)

6. Give an account of the structure and uses of the skin. (92)

7. What excretory matters are given off by the skin? (93)

8. Give a general account of the position and external form of the kidneys, mentioning the vessels which enter and leave them. (94)

9. Give an account of the minute structure of a kidney and of the functions of its several parts. (94)

10. What substances are excreted by the kidneys? What becomes of them after they leave that organ? (96)

11. Why is the blood in the renal vein the purest in the body? (97)

12. Why does the blood in the renal vein become venous when the nerves are irritated? (97)

13. Describe the position and structure of the bladder. (97)

CHAPTER XI.

1. Where is the cerebro-spinal nervous system situated, and where the sympathetic? (98-111)

2. Give an account of the spinal cord and its membranes, more especially as shown by a transverse section. (99)

3. How many pairs of spinal nerves are there? What is the difference in structure and formation between their anterior and posterior roots? (100)

4. What are nerve centres, and how do they differ in structure and function from nerves? (98)

5. Explain what is meant by reflex action, and give an example. (102)

6. Draw a diagram showing the direction which the afferent and efferent nerves take in the spinal cord. (103)

7. Give a general account of the external form of the brain, mentioning the structures which are to be seen both above and below. (105)

8. What nerves are given off from the brain and medulla oblongata, and what are their functions? (109)

9. Why are the first and second nerves called false nerves? (111)

10. Explain the positions of the following parts of the brain:—arbor vitæ, pons varolii, crura cerebri, corpus callosum, 3rd ventricle, pineal gland, pituitary body, foramen of Munro, and lateral ventricles. (106)

11. If the left side of a man's brain were injured which side of the body would you expect to become paralysed, and why? (104 and 108)

12. State what you know regarding the special functions of the cerebral hemispheres, cerebellum, medulla oblongata, and corpora quadrigemina. (108)

13. Give an account of the sympathetic nervous system and also of its distribution and functions, so far as they are known. (111)

14. What is meant by vaso-motor centres, and where are they situated? (112)

15. Explain the influence of the sympathetic and pneumo-gastric nerves upon the heart. (69)

16. What are the general functions of the nervous system? (98)

CHAPTER XII.

1. What is meant by a sensation? How are sensations brought about? (113)

2. Mention some sensations which do not seem to be definitely localized. (113)

3. Explain what is meant by the muscular sense. (114)

4. How many senses are men said to possess? Name them. (114)

5. Where are the organs of touch situated, and where is this sense most acute? (114)

6. What are tactile corpuscles, and where are they situated? (114, 115)

7. What nerves are chiefly concerned in the sense of touch? (115)

8. How may the sensitiveness to touch be readily tested? (115)

9. Where are the organs of taste situated? (115)

10. Describe the general structure of the tongue and its papillæ. (116)

11. Describe the structure and position of the bodies which are called *tasting-goblets*. (117)

12. What nerves supply the organs of taste? (118)

13. What other sensations are often very closely connected with those of taste? (118)

14. Where is the organ of smell situated? (118)

15. Explain what is meant by the anterior and posterior nares. (118)

16. Give a general description of the nasal chambers. (118, 119)

17. Explain precisely the positions of the turbinal bones and the cribriform plate. (118)

18. What are the bodies termed olfactory cells? (119)

19. Give an account of the manner in which the sensation of smell is produced. (119)

20. What nerves are distributed over the nasal chambers? What parts are supplied by each of these nerves? (119)

21. What portions of the nasal chambers are ciliated? (119)

22. Why do we sniff when we want to smell an odour more distinctly? (120)

23. Where is the organ of hearing situated? (120)

24. Where are the external ear, middle ear, and internal ear? (120)

25. Describe the general structure of the external ear. (121)

26. Where is the membrane of the drum situated? (121)

27. Describe the forms and relations of the small ear-bones. (122)

28. With what parts do the fenestra rotunda and fenestra ovalis communicate? Where is the eustachian tube? (122)

29. Describe the positions of the stapedius muscle and tensor tympani, and explain their uses. (122)

30. Describe the mutual relations of the semicircular canals, ampullæ, and vestibule. (123)

31. What relation subsists between the membranous labyrinth and the bony labyrinth? (123)

32. What is meant by perilymph and endolymph? (123)

33. What are otolithes, and where are they found? (123)

34. What and where is the cochlea? Explain what are meant by the scalæ. (124)

35. Explain the positions of the fibres of Corti, the crista spiralis, and the membrana tectoria. (125, 126)

36. What nerves supply the organs of hearing? (126)

37. Explain fully the manner in which sound is transmitted from the air to the auditory nerves. (126–128)

38. What functions are usually ascribed to the membranous labyrinth and the cochlea? (128)

39. Describe the positions of the organs of sight. (128)

40. Draw a diagram of a horizontal section of an eye, showing the position of its various parts. (129)

41. Explain the structure and uses of the iris. (129 and 134)

42. Explain the structure and uses of the crystalline lens. (130 and 133)

43. Explain the position and use of the ciliary muscle. (130 and 134)

44. Explain what are meant by the macula lutea and blind spot. (131 and 135)

45. Give an account of the microscopic structure of the retina. (131)

46. Explain how the eye is adjusted to near and distant objects. (134)

47. Give some of the reasons which lead us to infer that the function of the rods and cones is to receive the impressions of light. (136)

48. How long does the retina retain the impressions of light, and how may this be proved? (136)

49. Explain how it is that when we look at a bright spot on a dark ground and then look at a white sheet of paper a dark spot appears. (137)

50. What is the effect when a coloured spot is looked at instead of a black one? Explain the reason of the difference. (137)

51. What is colour blindness? (137)

52. How is it that an object appears upright, although the image formed upon the retina is upside down? (138)

53. Explain how it is that, although an image of an external object is formed upon each retina, the mind only perceives one impression of the object. (138, 139)

54. Explain how it is that objects are seen in relief. (139)

55. Explain how a stereoscope represents objects in relief. (139)

56. Explain the structure and use of the eyelids and of the muscles by which they are moved. (139)

57. Describe the structure and use of the lachrymal apparatus. (140)

58. By what muscles are the eyeballs moved and adjusted? (141)

CHAPTER XIII.

1. Describe the different kinds of movements which take place in the body. (145)

2. What is the structure of an ordinary muscle? How may a muscle be made to contract? (145 and 99)

3. Show the difference between striped and unstriped muscular fibre, and give examples of each. (146)

4. Name an instance of striped involuntary muscle. (146)

5. Give a short account of the manner in which muscles produce the movements of the body. (147)

6. Explain the different orders of levers. (147)

7. Show where in the human body each order of levers is exemplified. (148)

8. What is a joint? Give examples of imperfect and perfect joints, describing them fully. (149, 150)

9. What is a hinge joint, and what a ball and socket joint? (150)

10. Describe the structure of the atlas and axis vertebræ, and show how they articulate. (151)

11. Explain the movements of flexion, extension, adduction, abduction, and circumduction. (152)

12. Where is the organ of voice situated? (153)

13. Describe the cartilages and muscles of which the larynx is composed. (154)

14. What are the vocal chords, and where are they placed? (154)

15. Which muscles tighten, and which relax, the vocal chords? (155)

16. What is voice? (156)

17. Upon what does the compass and quality of voice depend? (156)

18. What is the difference between voice and speech? (156)

CHAPTER XIV.

1. Define the meaning of histology. (158)

2. What is a cell? (158)

3. What is epithelium? Where is it found? (158)

4. What is the difference between squamous and columnar epithelium? State how you would proceed if required to show both kinds under the microscope. (159)

5. What is ciliated epithelium? Where is it found, and how would you prepare some for the microscope? (159)

6. Where does globular epithelium occur? (160)

7. Explain the method of cutting thin sections of tissues by embedding them in wax. (160 and 176)

8. Of what is the epidermis composed? (161)

9. Describe the structure of the nails. (161)

10. Describe the structure of a hair. (161)

11. What is cartilage, and where is it to be found? (162)

12. How would you prepare cartilage for the microscope? (162)

13. What is connective tissue, and where is it to be found? (163)

14. How would you prepare it for the microscope? (163)

15. What is the structure of adipose tissue? (163)

16. What is the difference between elastic tissue and connective tissue? (163, 164)

17. Describe the minute structure of bone. (164)

18. How may it be prepared for examination with the microscope? (165)

19. Describe fully the minute structure of a tooth. (166)

20. Describe the microscopic appearance of striped and unstriped muscular fibre. (167)

21. How may they be prepared for the microscope? (168)

22. What preparation is necessary to show the blood vessels of the liver or kidney? (170)

23. Describe some process by which the cells of liver lobules may be seen. (170)

24. State how you would prepare the Meibomian glands for examination. (170)

25. Describe the structure of medullated and non-medullated nerve fibres. (170)

26. How may nerve fibre be prepared for the microscope? (171)

27. Describe the structure of ganglionic nerve corpuscles. (171)

28. How may ganglionic corpuscles be shown under the microscope? (172)

29. Explain some method of preparing sections of spinal cord for the microscope. (172)

30. Show how portions of retina may be prepared for the microscope. (173)

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